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How Population Density Influences Agricultural Intensification and Productivity: Evidence from Ethiopia

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HOW POPULATION DENSITY INFLUENCES AGRICULTURAL INTENSIFICATION AND PRODUCTIVITY:

EVIDENCE FROM ETHIOPIA

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ABSTRACT

Josephson, Anna Leigh. M.S., Purdue University, December 2013. How Population Density Influences Agricultural Intensification and Productivity: Evidence from Ethiopia. Major Professors: Jacob Ricker-Gilbert, Raymond J.G.M. Florax.

We use household-level panel data to estimate how population density impacts agricultural intensification and farm income in Ethiopia. We hypothesize that increases in population density affect agricultural intensification and farm income directly through information flows, institutional development, and reduction in transactions costs. Increases in population density also affect agricultural intensification and farm income indirectly through farm size, agricultural wage rates, and staple crop prices. We find that increases in population density lead to lower farm sizes, which has major implications for agricultural intensification and household well-being. Our analysis indicates that increases in population density cause farmers to purchase more inorganic fertilizer per hectare. This is due to population density's direct effects on market access. However, we find that population density does not have a statistically significant effect on maize yields, teff yields or farm income per hectare.

Keywords: Ethiopia, population density, landholding, productivity, intensification

JEL Codes: O13, O55, Q12, Q15, Q18

CHAPTER 1: INTRODUCTION

1.1 Land Use in Africa

Increasing population density is a critical challenge facing Sub-Saharan Africa (SSA), but few studies empirically estimate the effects of increasing population density on peoples' lives. With a current population in SSA of 900 million people, and projections for that number to double by 2050 (Population Reference Bureau, 2012), it is imperative to investigate the influence of growing population on people's lives and behaviors. Most people in SSA live in rural areas, which are experiencing rapid population expansion and correspondingly declining per capita farm size. Hence, the influence of increasing population density will have an enormous impact on agriculture, the ability of smallholder farmers to feed themselves and their families, and the food security of the continent.

When considering data on SSA, a paradox emerges. It is estimated that in the region about 201 million hectares, about 12 percent of total land, are unused. However, most of the rural population resides in densely populated areas (Muyunga and Jayne, 2011). Broadly, this suggests an agricultural development strategy that encourages production growth on the extensive margin, gained through expansion of cultivation into unused areas of land. Yet, it is not clear if this unused land is situated where most smallholder farmers live. Further, even if unused land exists in the areas where smallholders reside, it is unlikely that significant area expansion can occur. This is due to the underdeveloped state of African output per hectare markets, the inflexible nature of rural labor markets, and the traditional tenure system of allocating land, which dominates much of rural Africa. Additionally, environmental concerns such as erosion and salination, associated with clearing land, indicate that even if institutionally possible, such expansion may not be environmentally desirable for SSA. Therefore, as increasing production along the extensive margin is neither viable nor optimal, it is crucial to investigate realistic alternatives (Muyunga and Jayne, 2011).

Considering the difficulties associated with increasing production at the extensive margin, it is therefore important to increase productivity on the intensive margin. Relevant economic theories provide predictions regarding how growing population density will indirectly influence agricultural productivity. In this thesis, we draw primarily upon the theory of Boserup (1965), who presented an argument contrary to Malthus' (1798) projection of death and famine resulting from growing population. Specifically, Boserup hypothesized that increasing population density will lead to greater use of modern inputs, as well as a shift away from long-fallow periods towards annual and multi-cropping practices. Driven largely by prices, this process will ultimately result in increasing productivity per unit of land. Additional theories extend this argument to the value of land and the value of labor. These include von Thünen (1826) as well as Hayami and Ruttan (1970). Both theories utilize the underlying idea that prices drive behavioral changes, in order to adapt to changing conditions which result from growing population density. The former theory, which has found empirical support (Guiling et al., 2009; Delbecq and Florax, 2010), suggests that as land prices increase, farmers switch to higher value crops, in order to maximize value produced per hectare. The latter theory, often referred to as the induced innovation hypothesis, suggests that the positive relationship between population density and increased agricultural productivity occurs because the price of labor declines relative to the price of land, causing demand for labor-intensive and high-yield, modern inputs use to increase. The ultimate result is an increase in production per hectare. This theory has been applied in the context of Africa by Pingali and Binswanger (1984), and Binswanger and McIntire (1987).

It is also possible that population density itself is a driver of demand for inputs, and staple crop productivity. Population density can directly affect agricultural intensification through improved information flows, encouragement of the development and advancement of institutions and reduction of transaction costs. Regions with greater population density may be characterized by more rapid, and potentially more accurate, diffusion of information regarding market prices, availability of products, and transportation costs (Baerenklau, 2005; Foster and Rosenzweig, 2010; Conley and Udry, 2010; McMillen et al., 2011). This extended information may then encourage the development of institutions, in particular the improvement of markets, in order to capitalize on the availability of information. This in turn reduces transaction costs, and in doing so helps to boost productivity.

1.2 Land Use in Ethiopia

Ethiopia is a densely populated country with a current population of 88 million people, with expectations for that number to increase to 160 million by 2050 (Population Reference Bureau, 2012). A map of the country can be found in Figure 1.1. Ethiopia’s people and economy are dependent on agriculture, with agriculture contributing to over

85 percent of employment and 41 percent of gross domestic product (GDP) (World Factbook, 2012). The main export crops grown are coffee and chat (a mild narcotic). Maize and teff are the principle subsistence crops, cultivated by most smallholder farmers. The way in which Ethiopian farmers respond to increased population pressure will have an impact on millions of smallholder farmers in Ethiopia, as well as on food security and the economy of the nation.

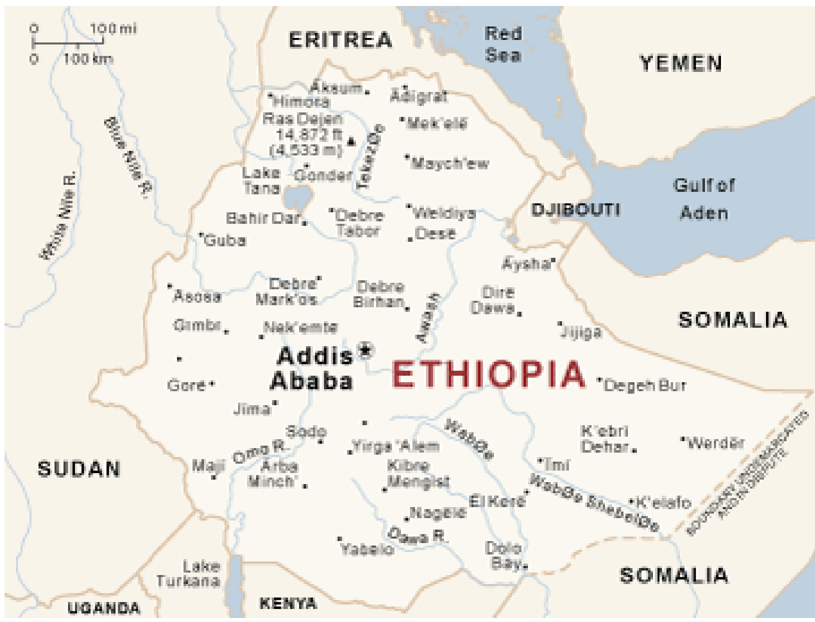

Figure 1.1: Map of Ethiopia
(National Geographic, 2013)

Data used in this analysis comes from three primary sources. First, we use six waves of household-level data collected between 1993 and 2004, covering 1,293 households. Second, we use population estimates and land estimates, gathered from two different Geographic Information System (GIS) databases, the Global Rural Urban Mapping Project (GRUMP) and Global Agro-Ecological Zones database (GAEZ).

Finally, we use qualitative data as a complement to the quantitative data, with information gathered in focus group discussions[1] conducted in Ethiopia in May 2012.

1.3 Objective

This thesis is part of a series of five collaborative studies that combine household-level panel data, GIS data, and qualitative focus group data to investigate the impacts of population density growth on agriculture in SSA.[2] The objective of this research is to identify the adaptations in agricultural methods that are necessary to sustainably grow enough food for an increasing population and to determine how increasing population density drives agricultural intensification. We also attempt to determine household level changes in agricultural practices which occur as agriculture intensifies.

We estimate the impact of population density on 1) household landholding; 2) factor and output prices including agricultural wage rates, fertilizer price, maize price, and teff price; 3) fertilizer use per hectare; 4) teff and maize output per hectare; and 5) farm income per hectare. We estimate these relationships using a correlated random effects (CRE) estimator, in an equation by equation model, as well as a seemingly unrelated regression (SUR) model.

Population density has both indirect and direct influences on agricultural productivity, and therefore on the demand for fertilizer, the supply of maize and teff, and

[1] These focus groups covered 12 of the 15 villages used in our survey, and were designed to complement quantitative data from the ERHS. Focus group discussions involved between six and eight individuals, over the age of 30, and included questions about farming, perceptions about population growth, well-being, land use, education, and believes regarding the past as well as the future.

[2] This research has been funded by the Bill and Melinda Gates Foundation and is a collaborative work between Purdue University, Michigan State University, and the International Food Policy Research Institute. Other countries included in this project are Kenya, Malawi, Mozambique, and Zambia. A comprehensive set of project results is forthcoming as a special issue of the journal *Food Policy*. For more information, please contact the author.

farm income. The indirect effect of population density on input demand and output supply comes from population's direct influence on wages, factor prices, and landholding. The direct effect of population density on input demand and output supply comes from leftover general equilibrium effects not captured in factor prices or landholding. Therefore, throughout this thesis, we consider both the indirect and direct pathways of influence and incorporate them both into our analysis.

1.4 Organization

The remainder of this paper is structured as follows. The next chapter presents some background on Ethiopia, considering the nation's institutional history and how present population density distribution and agricultural practices are influenced by this past. The conceptual framework and methods used in the analysis are presented in chapter 3. The final chapters, 4 through 6, present the data, results, and conclusions, respectively. An appendix is provided at the end of this thesis, giving more information on field group survey results and information from our discussions.

CHAPTER 2: LITERATURE REVIEW

Understanding the factors that determine why the people of Ethiopia have located in particular regions over time is important to the analysis of population density and agricultural productivity in the country. Historical, political, cultural, and agro-ecological factors have played an important role in people's decisions to locate in certain areas. Highland and lowland dynamics, resettlement programs, and land policy have all helped to shape the present distribution of population in Ethiopia and, congruently, population density and many agricultural practices. We discuss these relationships and their interplay throughout this chapter. Correspondingly we cite existing literature where relevant, and hence wind a literature review throughout the thesis.

2.1 Highland and Lowland Dynamics

Consideration of highland and lowland dynamics is necessary for understanding the process of resettlement and land policy in Ethiopia. Throughout its history, most of Ethiopia's population lived at high elevations, between 1,500 and 2,300 meters; see Figure 2.1. Throughout the structural transformation process and the expansion of markets more people began to migrate, and the lines between the different regions blurred (Pankhurst, 2009). However, the geographical, societal, and historical reasons for the varied development between the highlands and lowlands remain important, particularly for the analysis of population density and agricultural practices in the country.

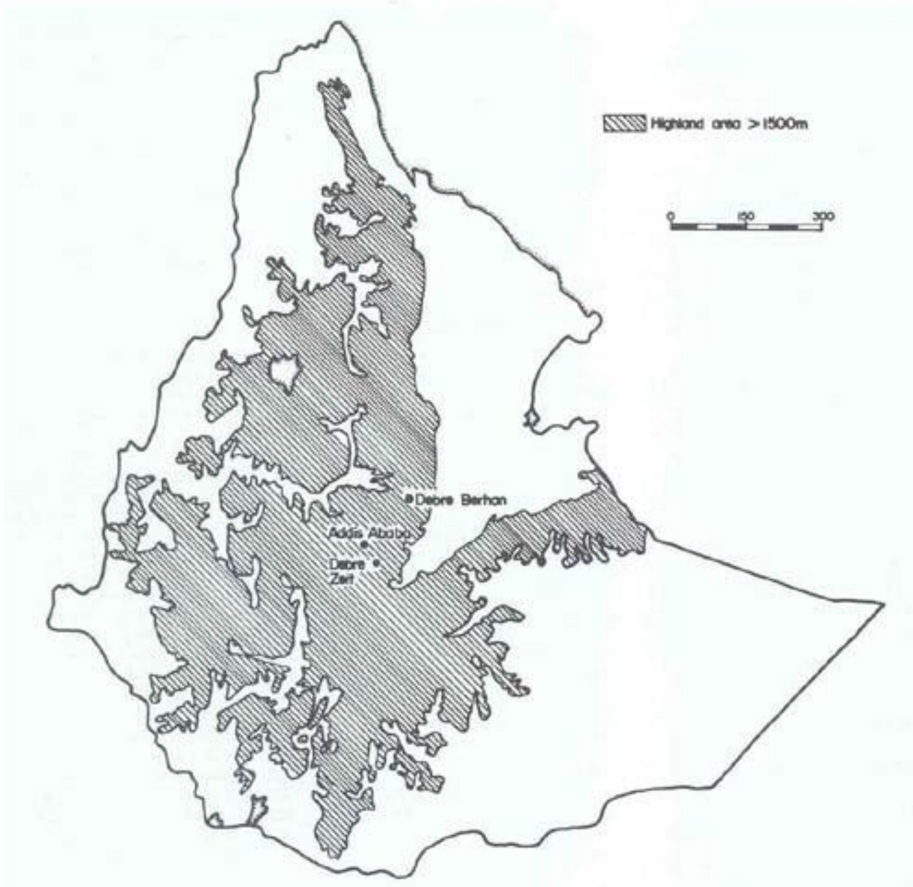

Figure 2.1**:** Ethiopian Elevation Map
(Ethiopian Review, 2013)

The highlands have many advantages which led to their early development and corresponding population expansion. First, the highlands benefit from steady rainfall and plateaus which were at the outset conducive to the development of agriculture. Second, the highlands benefit from centuries old technological innovations on ox-ploughs, which led to intensification of production and expansion of land under cultivation (Hammond, 2008). This also may have permitted and encouraged initial growth in population as it was possible to grow more food. Third, the land-tenure system which developed in the highlands is based on kinship groups that allocate cultivation rights to individuals. This institutional framework encouraged friendly relations, long-term security, and general tenure stability in the highlands, which generated investment in land and encouraged technology adoption. The combination of these factors permitted the development of agricultural surplus, along with early state and central social formations. The higher development potential and favorable conditions of the highlands encouraged population to grow and population density to correspondingly expand (Pankhurst, 2009).

Conversely, the lowlands suffer from developmental stagnation and have lower population density than the highlands. The lowlands are characterized by variable and limited rainfall, shallow soils, and constraints on human settlements due to limited water availability and foreign diseases, in particular malaria. These conditions did not encourage agricultural development, so technological innovations in the lowlands did not progress beyond hoe and shifting cultivation techniques. As a result, the lowlands are primarily pastoral[3] with households frequently participating in seasonal migration and small-scale farming activities. Contrary to the highlands, these unfavorable conditions discouraged population density expansion and development of agricultural practices in the lowlands.

The historical and current physical, cultural, and economic differences between the highlands and lowlands, explain the variation in their population density as well as the diverse agricultural practices utilized in different areas. This impacts which strategies are appropriate for agricultural development.

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[3] Pastoralists primarily herd goats, although there are some sheep and cattle, as well.

2.2 Redistribution

Despite Ethiopians' historical inclinations to settle in one location or another, the Ethiopian government has practiced land redistribution for decades. Redistribution, often referred to as "resettlement" or "villagization", has occurred due to overcrowding throughout the Ethiopian highlands. These practices, which began in the nineteenth century, continued into the twentieth century as cropland available to each family declined drastically due to rising population. In redistribution programs, families were moved from one, generally more populated region (often in the highlands), to another, less populated region (often in the lowlands). This process occurred forcibly during the 1970s and 1980s, and voluntarily during the 1990s and 2000s (Pankhurst, 2009).

In resettlement programs, during the 1970s and 1980s, under the Marxist Derg government, households were moved to seven randomly selected sites. These sites had not been analyzed by ecologists, agronomists, or economists to determine the influence that the new population might have on the land or how the land might receive such a large influx of people. Furthermore, the resettlers and the host populations were not consulted about the programs (Tareke, 2009). The locations chosen for resettlement were largely ill-suited for agriculture and in 1971, the first year of the program, as many as 5.5 percent of those resettled died of starvation. In addition, since many of these locations were in the lowlands, many settlers died of diseases that did not exist in the highlands, in particular malaria (Tareke, 2009). Cultural factors and ethnic strife also generated problems between the resettled and host populations. As a result, as many as 14 percent of resettled families ultimately returned to their original homes or moved to urban areas (Tareke, 2009).

A voluntary version of the resettlement program has been attempted under the present federal democratic government. However, this program was only voluntary in the sense that those being relocated were given a choice about doing so. Host populations were still not consulted. In the regions where families were resettled, land was often seized from already established households to give to arriving settlers. As a result, the program was largely unsuccessful, primarily due to animosity from host populations. Further, land seizure generated feelings of tenure insecurity that remain problematic across the country today, and continue to influence agricultural practices and productivity. It has been suggested that households which were redistributed, and remain insecure about tenure, still have less land, and despite increased propensity to use modern inputs, have generally lower output per hectare per hectare (Ali et al., 2011).

Once again, many resettlers have returned to their original homes. However, some focus group participants from our May 2012 indicated that they were participants in the resettlement program from the 2000s and were pleased with their new home. This favorable outlook was largely due to the greater availability of land in the region, although many voiced concerns about declining soil quality and increased disease rates.

Even with numerous resettlement programs in Ethiopia, the distribution of land is highly unequal (Kebede, 2006). This indicates that there has been a lack of success in attempts to equalize land ownership in the nation, even although this was a goal of redistribution programs. Overall land redistribution and resettlement programs in Ethiopia have been perceived as unsuccessful.

2.3 Land Tenure

It is not surprising that the Ethiopian government's resettlement practices have generated a sense of tenure insecurity among smallholders. This insecurity, combined with the historical relationship between the highland and the lowland populations, has repercussions for land use and agricultural practices in the country. As population density has increased, tenure rights have become even more tenuous, further straining already tried relationships.

All land in Ethiopia is officially owned by the government. This has been true since the Marxist Derg government took power in the 1970s and continues in the present federal democratic republic. Specific land use rights, however, are granted to every Ethiopian who wants to engage in agriculture. In principle, this guarantees land to any native citizen who desires to make a living by farming. When this system was put in place in 1995, it increased demand for land, so the federal government undertook a program of land reassignment to ensure that the law was carried out. These new assignments of land were intended to occur through administrative reallocation of land. However, the process generated conflict and undermined existing tenure security. As a result, the redistribution program threatened the new government's popularity. Therefore, in 1997, the constitution was updated, and the federal government ceded the responsibility of land allocation to individual regions (Jemma, 2004). Hence, present land policy is dictated by the federal government, but is carried out by individual regional governments.

Present land policy does not allow for the legal sale of land, although inheritance of land is legal (Ali et al., 2011). This land policy creates a weak rental market (Teklu, 2008), encourages urban migration (de Brauw and Mueller, 2012), and fosters a general feeling of tenure insecurity (Holden and Yohannes, 2002; Devereux, 2000; Ali et al., 2005; Deininger and Jin, 2006). In addition to feelings of insecurity indicated in the literature, our field group discussants in May 2012 regularly mentioned insecure feelings of tenure and anxiety about rights to their land. While some of this resulted from previous redistributions, many participants also mentioned a "use it or lose it" policy, in which un-used or under-used land may be seized by the government. This undermines tenure insecurity, and further discourages agricultural practices centered on fallow periods.

One interesting finding that emerged from the focus group discussions was that farmers in areas with good market access felt less secure in their tenure. This was especially true in the village of Sirbana located along the highway between Nazareth and Addis Ababa. In recent years investors built large-scale flower farms for the international export market. Although many members of the community were able to find jobs at the flower farms, they also felt their land could be seized at any time in order to expand the flower cultivation projects.

The focus group discussions also revealed that tenure insecurity continues to influence input decisions and therefore agricultural productivity and intensification of farmers. Many smallholders felt that their feelings of insecurity increase the amount of investment which they put into their land, and therefore influence their agricultural practices. Although this is a perception from farmers in our field group surveys and a body of literature (Holden and Yohannes, 2002; Deininger et al., 2009; Deininger and Jin, 2006), some studies have noted that the reverse is actually true (Pender, 2001). Ali et al. (2011) in particular noted that limited tenure rights negatively influences investment in Ethiopia, particularly in the case of tree crops, despite beliefs of farmers that investment was actually increased.

2.4 Population

Exacerbating the issues of redistribution and insecure tenure is the large and persistent increase in population throughout Ethiopia. With an United Nations (UN)-projected growth rate of 3.2 percent annually, the population is expected to reach 160 million people by 2050 (Population Reference Bureau, 2012). This growth is largely driven by the nation's young age structure, a fertility rate of 5.1 children per woman, and fewer than 10 percent of women using contraception.

As previously discussed, the distribution of population in Ethiopia is important for determining relative densities. The UN projects that most population growth in the next several decades will occur in the highlands, due to rising disease rates and increasingly poor environmental conditions at lower altitudes. Further, all focus group participants expressed concern over the growing population and the constraints on farming associated with an increased demand for land. Many noted that farm sizes are decreasing due to large families and longer lifespans in older generations. These concerns were even greater in highland villages.

Ethiopia's economy is dependent on agriculture and a strong relationship exists between population density and agricultural productivity. Agriculture contributes 41 percent of GDP and over 85 percent of employment (World Factbook, 2012). The way in which Ethiopian farmers respond to increased population pressures will have an impact on millions of smallholder farmers in Ethiopia, as well as on the food sustainability and independence of the entire country.

CHAPTER 3: METHODOLOGY

This section presents the outline for our estimation of the impact of population density on landholding, factor prices, input demand, output supply, and farm income. We additionally discuss the indirect and direct pathways through which population density influences supply of staple crops, demand for inputs, and the influence which it has on agricultural productivity.

3.1 Methodology Overview

Our conceptual and empirical model is motivated by Boserup (1965) and Hayami and Ruttan (1970). Their theories both postulate that prices will influence supply of staple crops and demand for modern inputs. Therefore, we first discuss the role of population density on landholding and factor prices. As land rental markets in Ethiopia are thin and under-developed, prices for land are unreliable. Therefore, we use farm size as a proxy for the price of land. Second, we conceptualize how population density influences a utility maximizing household's demand for modern inputs, supply of staple crops, and farm income. Table 3.1 presents a full list of explanatory variables used in our analysis. Table 3.2 also shows these variables, displayed in a manner that reflects where they appear in the different equations, which will be discussed later in the chapter.

Our hypothesis is that population density has both indirect and direct influences on agricultural productivity. The indirect effect of population density on input demand, output supply, and farm income comes from its direct influence on wages, fertilizer prices, food prices, and landholding. These factors in turn have a direct effect on agricultural productivity, so we obtain the indirect effect (partial derivative) on productivity with respect to population density. The direct effect of population density on input demand, output supply, and farm income comes from general equilibrium effects not captured in factor prices or landholding, such as improved information and institutions, as well as reduced transaction costs. Figure 3.1 shows these relationships in a flowchart.

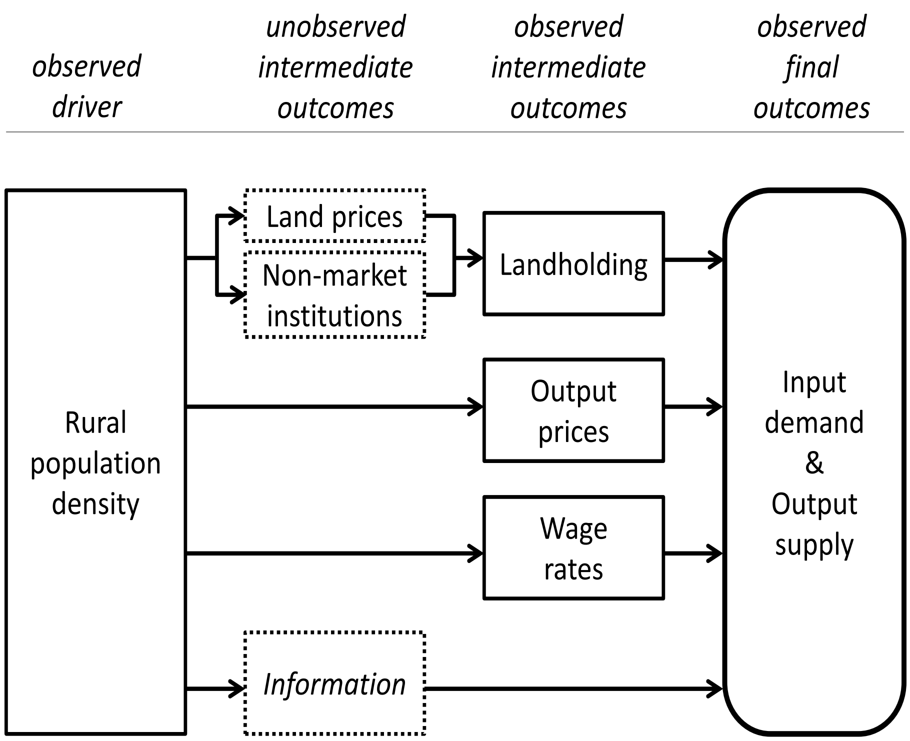

Figure 3.1: Indirect and Direct Influences of Population Density on Input Demand and Output Supply (Chamberlain, 2013)

Table 3.1: Variables Used in the Empirical Analysis, with Definitions

Dependent variables:	
Fertilizer use / cultivated area	Kilograms of fertilizer used per cultivated area (hectares) in a year
Maize yield	Kilograms of maize produced per hectare in a year
Teff yield	Kilograms of teff (white) produced per hectare in a year
Income / cultivated area	Farm income (birr) per cultivated area (hectares) in a year
Landholding*	Amount of land owned by a household (hectares)
Daily wage*	[Log] Wage rate for agricultural labor per day (birr)
Fertilizer price*	[Log] Price of fertilizer per kilogram (birr)
Prices*	[Log] Previous year prices (birr) of maize and teff per kilogram
Regressors:	
Population density*	Total population per square kilometer land – constructed using GRUMP estimates for population and GAEZ population for land
NPP	Net primary productivity (NPP) is a measure of the rate at which chemical energy is stored as biomass in a given period, proxy for agricultural production potential in a particular area (mass in grams of carbon per square meter per year)
Elevation	Elevation of the area of interest (meters)
Elevation squared	Elevation squared of the area of interest (meters squared)
Value of assets	Sum of value of assets of household (birr)
Agricultural cooperatives	Number of agricultural cooperatives in the respective area
Distance to cooperative	Distance, in kilometers to the closest agricultural cooperative (km)
Distance from the capital	Distance, in kilometers, from the capital to the village (km)
Distance to a paved road*	Distance, in kilometers, from the village to a paved road (km)
Rainfall 10-year average*	Rainfall average for the ten years prior to the year of interest (mm)
Annual rainfall average*	Rainfall average for the year of interest (mm)
Female headed household*	Dummy variable: if household is female headed = 1
Recent death*	Dummy variable: if household experienced recent death of adult (over 18) in household = 1 (proxy for shock to a household)
Land lost during redistribution	Dummy variable: if household lost land during redistribution in 1995 = 1
Highest grade*	Level of education attained by household head (0 through 14, with 13 indicating some college, 14 indicating college degree)
Adult equivalents*	Number of adult equivalents in household
Oxen*	Number of oxen owned by household

Note: An * denotes that a time average of the variable is also included in regressions

Table 3.2: Variables Used in Empirical Analysis

	landholding	maize price	teff price	fertilizer price	daily wage	income	fertilizer use	maize yield	teff yield	female headed	recent death	highest grade	land lost	adult equivalents	oxen	asset value	cooperative distance	road distance	capital distance	net primary productivity	ten year rain average	annual rain average	agricultural cooperative	population density	elevation	elevation squared	year dummy
landholding	/									x	x	x	x	x	x	x				x				x	x	x	x
maize price		/															x	x	x	x	x		x	x	x	x	x
teff price			/														x	x	x	x	x		x	x	x	x	x
fert. price			/						x							x	x	x	x	x		x	x	x	x	x	
wages					/					x		x												x	x	x	x
income	x	x	x	x	x	/				x	x	x	x	x	x	x				x		x		x	x	x	x
fert. use	x	x	x	x	x		/			x	x	x	x	x	x	x	x	x		x	x			x	x	x	x
maize yield	x	x		x	x			/		x	x	x	x	x	x	x				x		x		x	x	x	x
teff yield	x		x	x	x				/	x	x	x	x	x	x	x				x		x		x	x	x	x

3.2 Farm Size and Population Density

Ex ante we expect changes in population density to influence cultivation practices and farm size. As land rental markets in Ethiopia are thin and under-developed, prices for land are unreliable. Therefore, we use farm size as a proxy for land price. This is based on the idea that as population density increases the price of farm land will increase as land per capita declines, which implies that land prices increase. Boserup (1965) postulates that when population density increases, farming intensity also increases. This is a result of farmers moving away from long towards short fallow practices, and ultimately to annual and multiple cropping systems. They do so in order to accommodate rising populations and increased demand for food. Further, as population increases, and land is passed down from parents to children, it is divided into smaller plots, leaving less land for each household. Hence, over time, cropping will become more frequent and will be done on smaller plots of land. For household i a community at time t, we considering landholding, l:

$$l_{it} = \alpha_l d_t + X_{lit}\zeta_l + v_{lit} \quad (1)$$

where the variable of interest l is the amount of land held by a household, measured in hectares. The subscript l refers to parameters of landholding. Landholding is largely determined by household factors, as well as by the influence of population density. In equation (1), population density is represented by d_t, and α_l is the corresponding parameter. A matrix, X_l, of household-level factors includes asset value, whether the household lost land during redistribution, the highest grade attained by the head of the household, whether the household is female-headed, the number of adult equivalents in the household, and the number of oxen which the household owns. The term ζ_l is the corresponding parameter vector and v_l is the error term.

In our analysis, landholding serves as a proxy for the price of land. As previously mentioned, land markets are thin due to institutional issues which discourage land rentals, and prohibit the purchase and sale of land. Therefore landholding should be regarded as a quasi-fixed factor that we would expect to decrease as population density increases.

3.3 Prices and Population Density

The effect of population density on input prices comes from the theory of induced innovation, adapted to the process of agricultural development by Hayami and Ruttan (1970). The theory implies that as population grows, ceteris paribus, land becomes scarce relative to labor. The change in the land to labor ratio causes the price of labor to decrease relative to the prices of land. At the same time, increased population density leads to increased demand for food. As a result, population growth may put upward pressure on food prices. We estimate all prices as the natural logarithm of each respective variable, in order to normalize the distribution of the data and interpret the coefficients as partial elasticities.

3.3.1 Wages

We estimate the logarithm of daily agricultural wages w for household i at time t as:

$$log(w_{it}) = \alpha_w d_t + X_{wit}\xi_w + G_{wt}\gamma_w + v_{wit} \quad (2)$$

where population density is represented by d_t, and α_W is the corresponding parameter. The subscript w refers to parameters of wage. A vector X_w of household-level factors includes whether a household is female headed and the education level of the head of household; with a corresponding parameter vector ξ_w. A matrix G_w of community-level variables includes the number of agricultural cooperatives in the region, the distance from the village to the nearest to the agricultural cooperative, the distance of the village from the capital the net primary productivity of the soil in the area (NPP), and a ten-year rain average; with a corresponding parameter vector γ_w and the error term is v_w.

3.3.2 Staple Crop Prices

Similarly, we can estimate previous years' log prices p^c of maize or teff received by household i at time t as:

$$log(p^c_{it}) = \alpha_{p^c} d_t + G_{p^c t}\gamma_{pc} + v_{p^c it} \tag{3}$$

where the output price of interest, represented by p^c, is either the price of maize or the price of teff. The subscript p^c refers to parameters related to the prices of staple crops. We use lagged prices, based on the previous rounds' prices[4], in order to be able to connect this equation to other equations in the system of equations, presented later.

Prices are determined by community factors, including distance to an agricultural cooperative and the net primary productivity of the soil. As previously: d_t represents population density, while α_{p^c} is the corresponding parameter. A matrix G_{p^c} of

[4] For the first round in our data, 1993, we use data collected in 1989. The year 1989 was the first round of the ERHS, but we have chosen not to use it in our study. This round had fewer households than later rounds, and also was limited in scope. For 1994, we use 1993 prices, for 1995, we use 1994 prices, and so on.

community-level variables includes the distance from the nearest agricultural cooperative, the number of agricultural cooperatives, the distance from the village to the capital, the net primary productivity of the soil in the area (NPP), and a ten-year rain average; with a corresponding parameter vector γ_{p^c} and the error term is v_{p^c}.

3.3.3 Fertilizer Price

Finally, we estimate the log price of fertilizer, p^f, for household i at time t as:

$$log(p^f_{it}) = \alpha_{p^f} d_t + X_{p^f{}_{it}} \xi_{p^f} + G_{p^f{}_t} \gamma_{p^f} + v_{p^f{}_{it}} \tag{4}$$

where the input price of interest estimated by p^f is the price of fertilizer. As mentioned in the previous section, prices are largely determined by community factors. As previously: d_t represents population density, while α_{p^f} is the corresponding parameter. A matrix X_{p^f} of household-level factors includes only whether a household is female headed and ξ_{p^f} is the corresponding parameter vector. A vector G_{p^f} of community-level variables the number of agricultural cooperatives in the region, the distance from the village to the nearest to the agricultural cooperative, the distance of the village from the capital the net primary productivity of the soil in the area (NPP), and a ten year rain average and γ_{p^f} is the corresponding parameter vector. Again, the error term is v_{p^f}.

3.4 Demand for Modern Inputs and Output of Staple Crops

The increase in the price of staple food crops should induce a supply response where farmers adopt technology to increase production of staple crops. Therefore, an increase in population density induces farmers to further intensify and adopt modern inputs, in order to increase output on smaller plots of land. However, this assumes that farmers have adequate resources to access such inputs as their farms become smaller. This is not always the case, particularly as population becomes denser, and households face the constraints of small farm size and limited resources, such as access to credit that could be used to purchase modern inputs like fertilizer. Below, we provide more details for fertilizer use, staple crop production, and farm income.

3.4.1 Fertilizer Use

For household i at time t, demand for modern inputs such as chemical fertilizer, denoted by y_f, is:

$$y_{fit} = \alpha_f d_t + \omega_f log(w_{it}) + \pi_f log(p_{fit}) + \lambda_f l_{it} + R_{fit}\rho_f + G_{ft}\gamma_f + \epsilon_{fit} \qquad (5)$$

Population density, d_t, along with its parameters α_f, are as previously defined. The subscript f refers to parameters related to the use of fertilizer. Prices, p_f, includes the price of fertilizer and l represents landholding. π_f and λ_f as the corresponding parameters. Wages, w, is also included as an explanatory variable along with its parameter, ω_f. A vector G_f of community-level variables includes the net primary productivity of the soil, the number of agricultural cooperatives, distance to an agricultural cooperative, and a ten-year rain average. γ_f is the corresponding parameter vector. A matrix of household-level factors, R_f, includes the household's value of assets, whether the household lost land during redistribution, highest grade attained by the head of household, whether the household is female headed, and whether there was a recent death in the household while ρ_f is the corresponding parameter. ϵ_f is the error term.

3.4.2 Staple Crops

In the equation for output supply, represented by both maize and teff yield, y_s, for household i at time t, is:

$$y_{sit} = \alpha_s d_t + \omega_s log(w_{it}) + \pi_s log(p_{sit}) + \lambda_s l_{it} + R_{sit}\rho_s + G_{sit}\gamma_s + \epsilon_{sit} \tag{6}$$

This equation represents either maize or teff output supply. The subscript refers to parameters related to the yield of staple crops. All terms are as previously defined, although in this case prices, include the price for the crop of interest in the equation and the price of fertilizer.

3.4.3 Farm Income

Finally, in the equation for farm income, y_m, for household i at time t, is:

$$y_{mit} = \alpha_m d_t + \omega_m log(w_{it}) + \pi_m log(p_{mit}) + \lambda_m l_{it} + R_{mit}\rho_m + G_{mit}\gamma_m + \epsilon_{mit} \tag{7}$$

All terms are as previously defined, although in this case prices, p_m, includes the price for both maize and teff, as well as the price of fertilizer. The subscript m refers to parameters related to farm income.

3.5 Direct and Indirect Pathways

In equations (1)–(4) the indirect pathways are measured through landholding, daily wages, and prices of maize, teff, and fertilizer.[5] In equations (5)–(7) the direct

[5] Both the within-estimator and the time-average estimator are included for all indirect factors. More information will be given on this in the following section.

pathways are measured, representing factors such as information flow, transaction costs, and institutions. When the direct and indirect pathways are added together, the influence of population density on each variable is determined.

In order to derive the effect of population density d on input demand, y_f, we rewrite equation (5) as:

$$y_{fit} = \alpha_f d_t + \omega_f log(w_{it})(d_t) + \pi_f log(p_{fit})(d_t) + \lambda_f l_{it}(d_t) + R_{fit}\rho_f + G_{ft}\gamma_f + \epsilon_{fit} \quad (8)$$

We define the total derivative of y_f, with respect to d as:

$$\frac{\partial y_{fit}}{\partial d_t} = \alpha_f + \frac{\partial y_{fit}}{\partial p_{ij}} \times \frac{\partial p_{it}}{\partial d_t} + \frac{\partial y_{fit}}{\partial l_{it}} \times \frac{\partial l_{it}}{\partial d_t} + \frac{\partial y_{fit}}{\partial w_{it}} \times \frac{\partial w_{it}}{\partial d_t} \quad (9)$$

which can also be written as:

$$\frac{\partial y_{fit}}{\partial d_t} = \alpha_f + \pi_f \times (\alpha_{p^f} + \alpha_{p^c}) + \lambda_f \times \alpha_l + \omega_f \times \alpha_w \quad (10)$$

We refer to α as direct effect of population density on the outcome of interest. In the case of fertilizer, α_f is the direct effect of population density on fertilizer demand. The indirect effect of population density on fertilizer demand through wage rates is α_{fw} and is equal to $\frac{\partial y_{fit}}{\partial w_{it}} \times \frac{\partial w_{it}}{\partial d_t}$ in equation (9), and $\omega_f \times \alpha_w$ in equation (10). The indirect effect + the direct effect give us the total effect of population density on fertilizer demand.

The effect of population density on maize and teff yield, and farm income is derived in an analogous manner.

3.6 Empirical Estimation

In our estimation we first run our model on an equation-by-equation basis, utilizing the correlated random effects estimator. We do so in order to address potential correlation between the entire history of the explanatory variables and the random household effects. These unobservable factors (denoted b_i) include characteristics such as motivation, risk aversion, and inherent ability of farmers. In order to use the CRE estimator we decompose the error ϵ, as $\epsilon = b_i + u_{it}$, where u_{it} represents the time-varying unobserved shocks. The CRE estimator is based on the assumption that the unobserved heterogeneity takes on the form of $b_i = \psi + \mu\overline{M}_i + u_{it}$ where $u_{ij} \mid M_{it} \sim N\,(0, \sigma_{it}^2)$. Here $\overline{M}_i$ is the time average of household level characteristics in all of the equations (Mundlak, 1978; Wooldridge, 2010). To functionalize the CRE estimator it is necessary to include $\overline{M}_i$ in the specification of the different equations. The CRE estimator produces coefficient estimates for the original (non-averaged) variables that are identical to those generated by a household-level fixed effects model (Wooldridge, 2010). The additional benefit from the use of the CRE estimator is that it does not remove time-constant covariates from the model, unlike a fixed-effects specification. As some variables considered do not vary over time (such as distance to an agricultural cooperative and whether a household lost land during redistribution), it is important to retain these variables without including a time-averaged version. The CRE estimator is implemented by running a simple pooled regression on the expanded model specifications. In order to correct for heteroskedasticity and correlation across time we use robust standard errors with non-zero covariances at the household level ("clustered" standard errors).

Next, we run the CRE-specification as a seemingly unrelated regression (SUR) model. As our system is non-recursive, it is worth noting that this estimation is the same as three stage least squares (3SLS). Further, it still allows a relationship between unobserved factors and observed variables. We control for heteroskedasticity and correlation within households in our equations through using a clustered bootstrap procedure at the household level (see Stata, 2013, for details), running 500 repetitions. The SUR setup assumes that equations are related, with the errors correlated across the system. As expected, the estimation results for the equation-by-equation approach and the SUR approach are very similar, and we therefore concentrate on the more efficient SUR results in our below discussion of the estimation results.

We argue that population density is exogenous in our equations in the sense that it is not correlated with household-level time-varying unobservable shocks. As reverse causality could be a potential problem we have tested for potential endogeneity of population density using the control function method, with agro-ecological factors serving as instruments for population density (Wooldridge, 2010). Using this method we found that endogeneity is not present in any of the equations. Finally, as we use the CRE method to deal with correlation between population density and time-constant unobserved factors, omitted variable bias should not be a problem, especially when we include agro-ecological factors, such as, elevation and its square, net primary productivity, and rainfall in all equations.

CHAPTER 4: DATA

Data used in this thesis comes from three sources. First, we use nationally representative household-level data on smallholder farms in Ethiopia. Second, we use GIS data, collected from GRUMP and GAEZ databases. Finally, we use qualitative data collected in Ethiopia in May of 2012 in field group survey discussions. All three sources are discussed in this chapter.

4.1 Ethiopian Rural Household Surveys

Household-level data used in this study comes from survey data sets collected in Ethiopia by the International Food Policy Research Institute (IFPRI). The nationwide Ethiopia Rural Household Survey (ERHS) is a panel dataset tracking approximately 1,500 households in eight survey waves over the twenty year period from 1989 to 2009. We use the center six waves of the survey, which include 1993, 1994, 1995, 1997, 1999, and 2004, and cover 1,293 households.

The households are located across 15 villages, which were selected to cover diversity in the farming systems in the country, including grain-plough areas in the Northern and Central highlands, as well as the enset-growing area and sorghum-hoe areas in the lowlands (Dercon and Hoddinott, 2011). Efforts were also made to include a span of population densities, which makes it an ideal source for this study; see Figure 4.1.

However, as the data only considers rural, non-pastoral households, it is not considered to be nationally representative, although it is broadly representation of small-holder subsistence farmers.

The data set includes consumption, asset, and income data, as well as household characteristics, agriculture and livestock information, food consumption, as well as on health and women's activities. The data set also includes community-level data on electricity, water, sewage, roads, and general facilities.

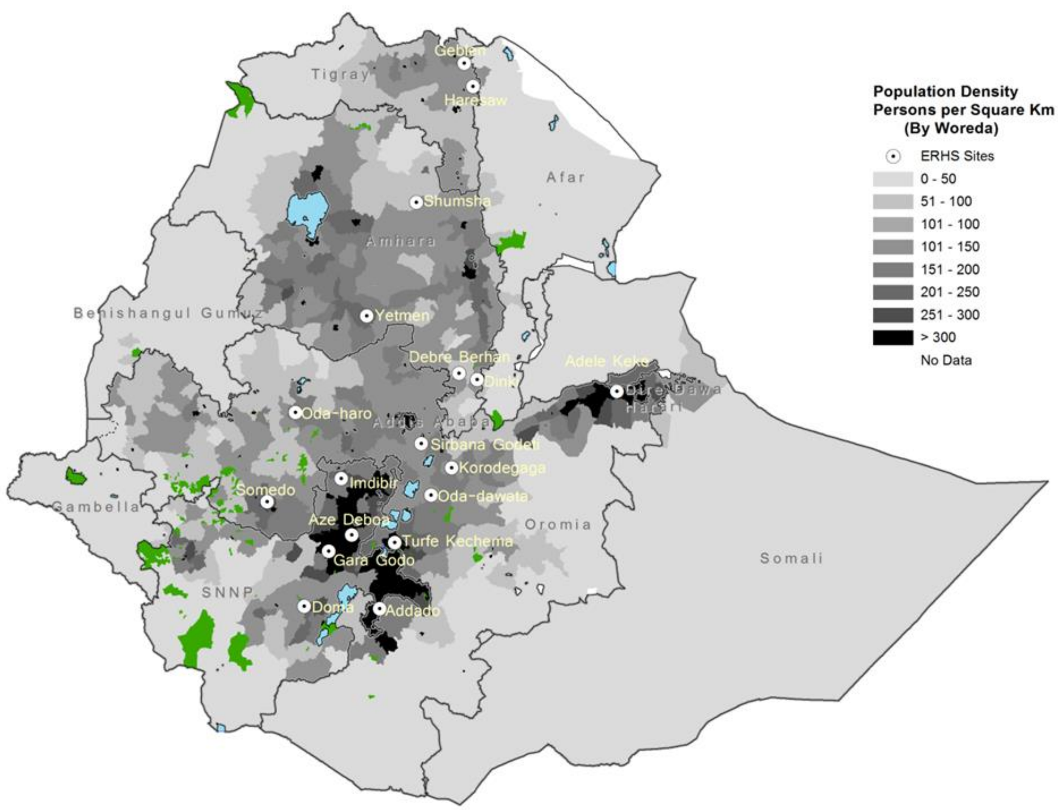

Figure 4.1**:** Ethiopian Population Density Map, with Survey Villages
(Heady et al., 2013)

4.2 GIS Data

We combined two regional databases describing spatial distributions of rural population (GRUMP and GAEZ; see below) to generate estimates of population density.

Estimates of rural population density are derived from the Global Rural Urban Mapping Project (GRUMP) database. The dataset provides gridded estimates of local population densities, beginning with sub-national census data and allocating the population to a specific area. This allocation is based on where people are generally most likely to settle. GRUMP separates the urban and rural components of local population with the rural component being equally allocated between all rural grid cells in the area.

Information on land resources was obtained from the Global Agro-Ecological Zones (GAEZ) 3.0 database. This data consists of gridded estimates of local land and agro-climatic resources, including soils, terrain, land cover, and other climate indicators. It also contains derived estimates of agricultural suitability and potential yields for a multitude of commodities under given management levels. Using the land cover components of the GAEZ database, we create three definitions of "land." Areas are classified as 1) under cultivation, 2) under cultivation or grassland, and 3) under cultivation or grassland or forest/woodland. The motivation behind the adoption of multiple definitions was to evaluate the robustness of the analysis to alternative definitions. Classification 1 reflects currently available farmland while classifications 2 and 3 indicate potentially available farmland, if adequate costs are incurred to alter grassland and forest land to farming. We use the latter and broader definition in our analysis[6], as Ethiopian farmers cultivate tree crops, which cannot be distinguished from forest or woodland in GAEZ. Additionally, forest and woodland areas are also used by farmers as grazing areas for animals. Therefore, using this broader definition of land allows for the capture of all potential uses of land by rural farmers.

We combine the GIS datasets on land and rural population at the level of one square kilometer grid cells. To generate the population density term, we took the estimates of population from GRUMP and divided those numbers by the estimates of land from GAEZ. In doing so, we determine the number of persons per square kilometer, or population density. In the construction of this variable, we omitted all pixels categorized as rural that contained less than 10 percent land or exceeded 2,000 persons per square kilometer, based on the assumption that populations over this level were approaching peril-urban status or were incorrectly categorized. Ultimately, our population density term is observed at the community-level, and population density does not vary over local groups of households.

4.3 Field Group Surveys

Finally, we utilize field group surveys conducted in twelve of the fifteen ERHS villages in May of 2012. Using questions designed to gain qualitative information about farmers' perceptions regarding population growth, land use, inheritance regulations, farming practices, children, and the future, we use their answers to extend our quantitative analysis and support the resulting conclusions. The primary concerns of

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[6] Although we chose this broader definition in this case, we have also tested with alternative, more conservative definitions of land, in order to test for robustness. Our results are similar, regardless of definition. For a copy of these results, please contact the author.

focus group participants were: 1) the rapid expansion of population across the country; and 2) the limited generation of new area suitable for agriculture, which in the past has generally been done by the government. These discussions made clear the challenges facing different communities, as well as measures being undertaken to address these problems. The insights from these surveys are incorporated throughout this thesis, as well as included as an appendix at the end of the thesis.

CHAPTER 5: EMPIRICAL RESULTS

This chapter presents the quantitative and qualitative results of our study including descriptive statistics and regression results, as well as insights from our field group discussions. We first present descriptive statistics regarding the relationship between population density and agricultural intensification. Subsequently, we discuss our results and the total effects of population density on agricultural productivity.

5.1 Descriptive Statistics

Based on agricultural data from the ERHS and population density data derived GRUMP and GAEZ, we construct six lowess[7] smoothing graphs where population density is on the x-axis and the measures of agricultural intensification are on the y-axis. In order to understand these graphs, we have constructed an associated table with population densities at different percentile levels; see Table 5.1. This table and the corresponding graphs in Figures 5.1 through 5.6 use the same definition of land as our regression results, so land is not weighted by arability.

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[7] Lowess provides a locally weighted scatterplot smoothing. The basic idea behind the function is to generate a new variable which, for every *y*-variable, contains the corresponding smoothed value. The smoothed values are obtained by running a regression of the *y*-variable on the *x*-variable. In lowess, the regression is weighted so that the central point (x_t, y_t) gets the highest weight and points that are further away receive less weight. Estimated regression lines are used to predict the smoothed value for the *y*-variable only. This is repeated for all remaining values. Lowess is considered to be a desirable smoother due to its locality – it tends to follow the data. Polynomial smoothing methods, for example, are global in what happens on the left of a scatterplot, and can therefore influence fitted values on the right. The same is not true for a lowess smoothing method, though, due to its central focus (see Stata 2013, for details).

Table 5.1: Population Density: Percentiles and Mean

Percentile	10th	25th	50th	75th	90th	Mean
Population Density (persons / km^2)	80	107	158	279	394	210

The descriptive figures illustrate the unconditional effects of population density on the factors of interest, as they do not hold all other factors constant as in a regression context. As such, these figures describe and illustrate general trends for agriculture in Ethiopia, which are instructive for informing the overall results of our analysis and conclusions.

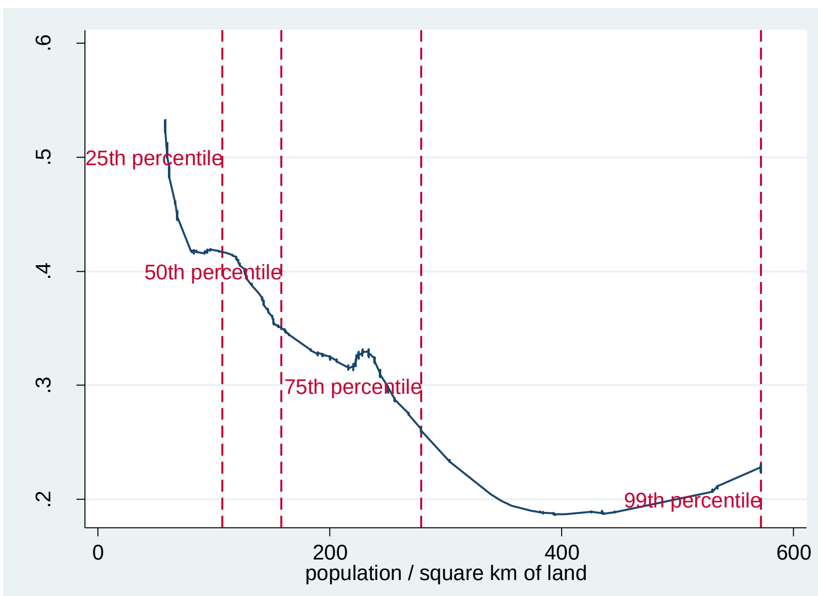

Figure 5.1: Landholding per Adult Equivalent

In Figure 5.1, the amount of land held by each adult equivalent decreases constantly. Although there is a slight increases around 250 people per square kilometer (just below the 75th percentile), the amount of land consistently decreases across population densities. Since the quantity of land in an area is ultimately fixed, less land is available for each individual as population grows, causing the landholding per adult equivalent to decrease. This follows Boserup, who predicted that population density will cause increased demand for land, represented ultimately by less land held by person.

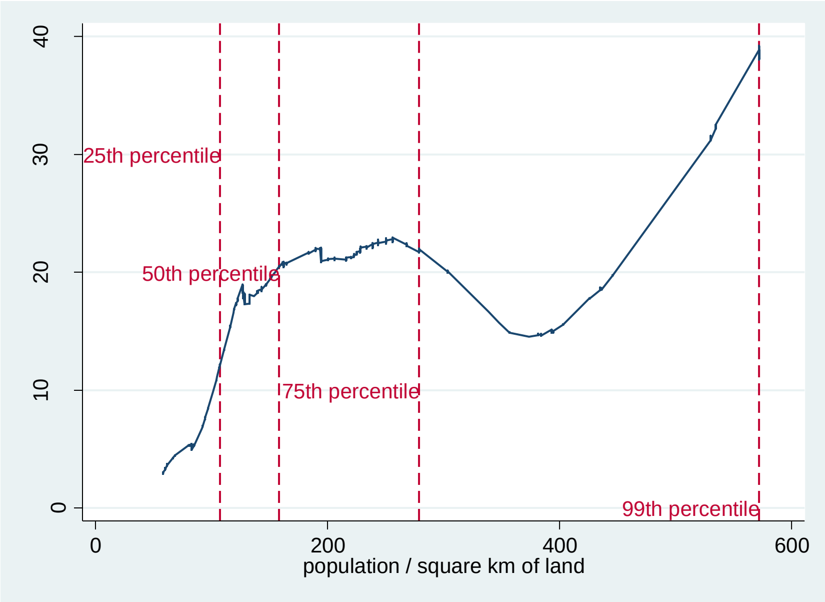

Figure 5.2: Adult Equivalents per Cultivated Area

In Figure 5.2, the number of adult equivalents per area cultivated increases as population grows, although there is a slight decline just below 400 people per square kilometer (just above the 90th percentile). As there are more individuals in an area, less land is available and therefore there are more people on the land area which is cultivated. This follows Boserup who predicted increased demand for land, and as a result, more people per unit of land, as population grows.

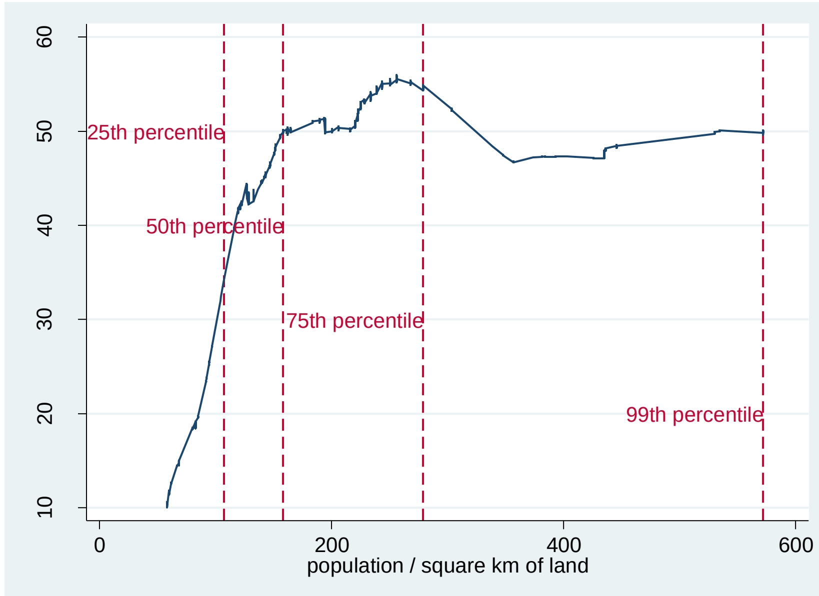

Figure 5.3: Fertilizer Use per Cultivated Area

In Figure 5.3, the expenditure on purchased inputs per hectare increases to around 300 people per square kilometer (just above the 75th percentile), and then declines slightly. This implies that there is some threshold at which people begin to use less fertilizer per hectare. There could be many reasons for this, including supply availability, credit constraints, and diversification to crops[8] which do not require fertilizer. Frequently in our field group discussions from May 2012, participants discussed lack of available credit to purchase fertilizer as being a significant barrier that prevented them from purchasing more fertilizer. This is likely worse in areas of high population density where small farm sizes limit credit availability with which to purchase fertilizer. Additionally, our focus group discussions revealed that some farmers in densely populated areas have diversified into to tree crops, such as coffee and chat, as they generally require less

[8] Diversification crops generally include cash crops, which are not typically grown. These include tree crops, such as coffee and chat, as well as vegetables, such as green beans, onions, and squash.

fertilizer. Due to barriers which influence input access in Ethiopia, fertilizer use is only used up until a point, after which, it is not used in regions of greatest population density.

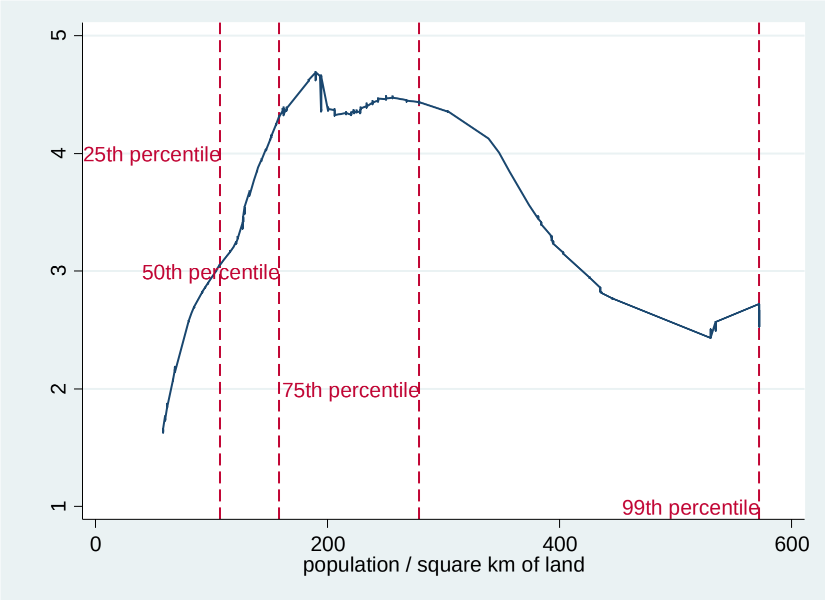

Figure 5.4: Daily Agricultural Wage

Figure 5.4 shows that hired agricultural wages decrease from around 300 people per square kilometer (just above the 75th percentile). With an increase in the number of people in a region looking for work, given the same number of jobs available, the price of labor will be driven down, as predicted by Hayami and Ruttan. This has strong implications for off-farm income and household income. Even if people work more hours they may not make as much money as off-farm laborers in the most densely populated regions, simply because the wages are so much lower in these regions.

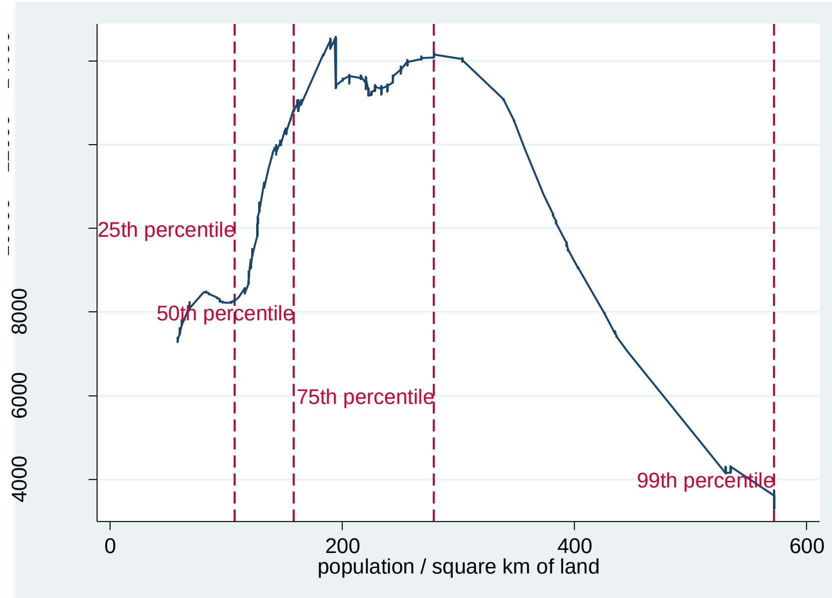

Figure 5.5: Farm Income per Cultivated Area

In Figure 5.5, farm income per hectare cultivated increases until around 350 people per square kilometer (just below the 75th percentile). This implies the highest population density has the least income per cultivated area and that the people at the middle population densities have the greatest income per cultivated area.

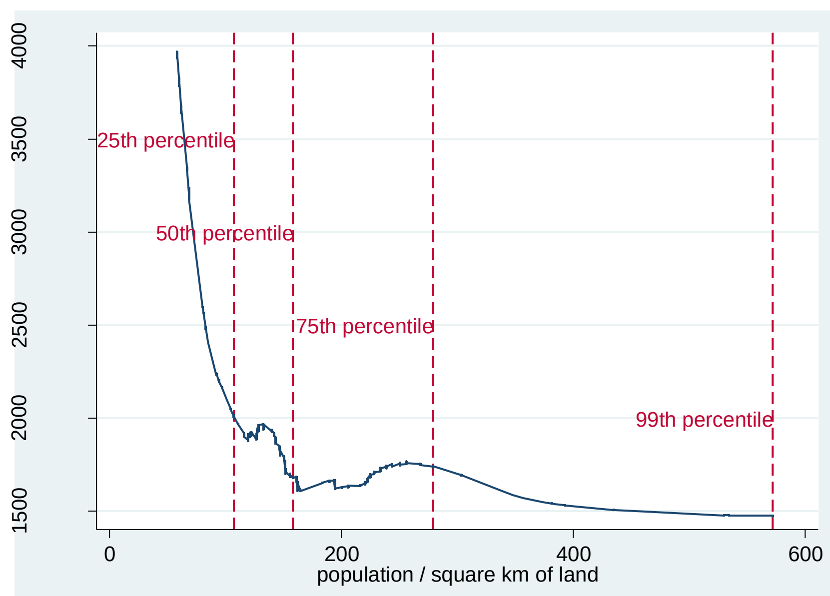

Figure 5.6: Asset Value per Adult Equivalent

In Figure 5.6 the value of assets per adult equivalent decreases as population density increases. It is quite high initially, but then decreases consistently beginning around 150 people per square kilometer (just above the 25^{th} percentile). Assets serve as a proxy for wealth, and this graph implies that the poorest people are in regions with the highest population densities, decreasing from the least dense population densities which have the wealthiest individuals. Following Figure 5.5, those who have less income, at the densest regions, also have the least value of assets.

These diagrams, all together indicate that landholding and cultivated area per adult equivalent decline with increased population density, and correspondingly farm income also declines. They also suggest that coping strategies, including working off-farm and using more labor-intensive inputs, may be problematic, the former due to low wage rates, and the latter due a threshold beyond which it is difficult to use fertilizer. These figures also suggest the existence of several thresholds, or turning points. These indicate that some agricultural adaptations to increasing population density, in particular fertilizer use (representing increased use of labor intensive inputs), are not possible beyond a certain point and therefore other strategies must be investigated. While these thresholds are not incorporated at this time into regression models, these lowess figures are able to give us general strategies and information regarding population density and intensification.

5.2 Estimation Results

In this section, we present results for factors affecting agricultural intensification and income using the linear correlated random effects specification estimated with a seemingly unrelated regression (SUR) estimator. Following Mundlak (1978), the specifications include a long-term household average of all time-varying variables, and a time-varying component of each variable. These former terms can be interpreted as the long-term effect of the variable of interest, over the 11-year period of the survey. The latter terms are equivalent to the fixed effects, or within estimator. We also include the joint direct effect of the time-varying component and the time-averages of each variable.

Each of our tables includes 3 columns. The first column shows the time-varying covariate, while the second column shows its time-average, where applicable. If the variable does not vary over time, it obviously it does not have a time-constant counterpart. The coefficients on the time-varying covariates are the within households estimators. The third column shows the results of a joint test which indicates the influence of the combined short-term and long-term effects, from the first two columns, and is referred to as the joint direct effect. In regard to population density, it can also be interpreted as the direct effect. The magnitude of this effect indicates the direction and total value of the two terms together.

5.2.1 Prices and Landholding

The results for factors affecting landholding, daily agricultural wages, prices of maize and teff, and fertilizer are found in Table 5.2 through Table 5.11. Tables 5.2, 5.4, 5.6, 5.8, and 5.10 are the results from the equation by equation models, and Tables 5.3, 5.5, 5,7, 5.9, and 5.11 are the results from the SUR models.

We first consider landholding. The direct effect of population density indicates that higher populations lead to significantly smaller landholdings. This effect suggests that, on average, a 10 person increase in population density decreases landholding by

0.013 hectares. Further, population density and its long-term average are both significant in the equation by equation and SUR models, suggesting that population density causes an increase of 0.03 hectares for every additional 10 people in the short term, while in the long-term, it decreases by 0.04 hectares. These results suggest that while population density may not influence landholding negatively in the short-term, it does decrease it in the long-run. The magnitude is slightly larger in the short-term in the SUR model, than in the equation by equation model.

For the other explanatory variables, we will only discuss the joint direct effects of each, for the sake of parsimony. Of these, the highest grade attained by the head of household, whether the household is female headed term, whether the household suffered a recent death, the number of adult equivalents, and the number of oxen are both significant in both models. First, for an additional grade attained by the head of household, there is an additional, increase in landholding of 0.05. This suggests that greater education results in greater landholding, and there is benefit to famers who continue in school. Second, if a household is female-headed, it holds 0.43 fewer hectares of land than households which are not female headed. This indicates that women hold less land than men, on average. Third, a death in the household increases landholding by 0.35 hectares. This increase may result from inheritance of the additional land from the deceased. Finally, an additional oxen or additional adult equivalent in the household results in an increase in landholding of 0.6 and 0.04 hectares, respectively. These findings makes sense, as households with more members require more land on which to produce more food, and they also have more available labor, which could be provided by family members or by oxen.

Table 5.2: Factors Affecting Landholding, CRE Equation by Equation

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	0.003***	-0.004***	-0.001***
	(0.001)	(0.001)	(0.0003)
Value of assets	2.61e-06		
	(3.05e-06)		
Land lost during redistribution	-0.028		
	(0.062)		
Highest grade	0.012*	0.050***	0.062***
	(0.006)	(0.012)	(0.010)
Female-headed household	-0.134**	-0.309***	-0.443***
	(0.054)	(0.094)	(0.078)
Recent death	0.014	0.390**	0.404**
	(0.027)	(0.173)	(0.181)
Adult equivalents	0.002	0.040**	0.042***
	(0.010)	(0.016)	(0.014)
Oxen	-0.013	0.587***	0.574***
	(0.018)	(0.071)	(0.066)
Net primary productivity	-1.27e-05		
	(1.89e-05)		
Elevation	-0.003***		
	(0.001)		
Elevation^2	5.71e-07***		
	(1.89e-07)		
Constant	5.91***		
	(0.834)		
Observations	7,758		
R^2	0.269		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

The dummy variable for whether or not the household lost land during the 1995 redistribution is also significant in the SUR. As discussed in the literature review chapter, massive land redistributions have taken place for decades in Ethiopia. The results of the SUR estimation indicate that if a family lost land, they now hold about 0.12 fewer hectares, on average, than a family who lost no land.

Table 5.3: Factors Affecting Landholding, CRE SUR

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land, in km^2	0.003***	-0.004***	-0.0013***
	(0.001)	(0.001)	(0.0003)
Value of assets, in birr	2.39e-06		
	(3.10e-06)		
Land lost during redistribution	-0.120*		
	(0.065)		
Highest grade	0.014**	0.037***	0.051***
	(0.006)	(0.012)	(0.006)
Female-headed household	-0.132**	-0.301***	-0.433***
	(0.055)	(0.091)	(0.043)
Recent death	0.023	0.332**	0.354***
	(0.027)	(0.162)	(0.090)
Adult equivalents	0.001	0.042***	0.043***
	(0.009)	(0.016)	(0.007)
Oxen	-0.011	0.619***	0.608***
	(0.018)	(0.067)	(0.032)
Net primary productivity	-1.17e-05		
	(8.55e-04)		
Elevation	-0.003***		
	(0.001)		
Elevation^2	5.24e-07***		
	(2.01e-07)		
Constant	5.78***		
	(0.87)		
Observations	7,758		
R^2	0.27		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

With a median farm size in our sample of 1 hectare, 0.12 hectares composes about a sixth of the average holding, and represents a substantial component of a household's average landholding.

Several community characteristics are also significant, including elevation and its square term in both the equation by equation model and the SUR model. Elevation effects are not marginal effects (as the other effects are), and significance is determined through a joint test. This is true in all cases when significance of elevation is discussed hereon.

Next we consider the results for factors affecting the log of daily agricultural wage. Factors affecting daily wages are included in Table 5.4 (equation by equation), and Table 5.5 (SUR). As wage rates are primarily determined by an employer, worker characteristics, rather than community or household characteristics, are likely to influence the wage. The direct joint direct effect results indicate that daily wage has a positive impact on population density; the coefficient suggests that over time, a 10 person increase in population density decreases daily wage by approximately 0.5 percent, on average. This finding suggests that in areas of higher population density labor prices rise slightly, possibly through the positive effects generated by market and institutional development, which provide more opportunities and higher wages for workers.

Table 5.4: Factors Affecting Log of Daily Wage, CRE Equation by Equation

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land, in km^2	0.0002*	0.0003*	0.0005***
	(0.0001)	(0.0002)	(0.0001)
Highest grade	-0.006*	0.022***	0.015**
	(0.004)	(0.008)	(0.007)
Female-headed household	0.032	0.031	0.063
	(0.022)	(0.053)	(0.049)
Elevation	-0.004***		
	(3.16e-04)		
Elevation^2	1.06e-06***		
	(7.87e-08)		
Constant	3.99***		
	(0.303)		
Observations	7,758		
R^2	0.123		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

Several household and community variables are also significant in influencing daily wages. First, higher education levels positively drive wages. In both the equation by equation and SUR models the coefficient for highest grade attained is positive and significant, as more education generally leads to better jobs and better pay. In the SUR, the results indicate that a higher grade increases wages by 0.044 for an additional grade attained. This follows field group discussions where many participants noted that better education leads to better jobs, although only high school education was perceived as important. Many discussants indicated that college did not guarantee success or employment, and therefore was not much more valuable than a high school education.

Table 5.5: Factors Affecting Log of Daily Wage, CRE SUR

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land, in km^2	0.0002**	0.0002	0.0005***
	(0.0001)	(0.0002)	(0.0001)
Highest grade	-0.009***	0.053***	0.044***
	(0.004)	(0.009)	(0.003)
Female-headed household	0.020	0.039	0.059***
	(0.023)	(0.051)	(0.021)
Elevation	-0.004***		
	(0.0003)		
$Elevation^2$	1.06e-06***		
	(8.45e-08)		
Constant	3.91***		
	(0.32)		
Observations	7,758		
R^2	0.11		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

Additionally, elevation and its square were significant, suggesting that wages are lower at higher elevations. This makes sense, following the distribution of population in Ethiopia, and its concentration in the highlands. In these regions, when population is most dense, it is likely that more people are looking for work, and therefore, depressing the price of wages.

Next, the results for the log prices for maize and teff can also be found in Tables 5.6 through 5.9. The results indicate that overall, population density negatively drives maize price and teff price. As population increases, a 10 person increase in population density decreases maize price and teff price by approximately 0.6 percent, for both crops.

Table 5.6: Factors Affecting Log of Maize Price, CRE Equation by Equation

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	-0.0002***	-0.0004***	-5.94e-04***
	(0.0001)	(0.0001)	(1.12e-04)
Number of cooperatives	-0.374***		
	(0.010)		
Distance to cooperative	-0.014***		
	(0.003)		
Distance to capital	-0.002***		
	(1.06e-04)		
Distance to a paved road	-0.005***	0.043***	0.038***
	(0.001)	(0.003)	(0.003)
Net primary productivity	1.39e-04***		
	(7.94e-06)		
Ten year rainfall average	-3.73e-04***	-0.002***	-0.003***
	(5.48e-05)	(1.03e-04)	(7.55e-05)
Elevation	-0.002***		
	(3.24e-04)		
Elevation^2	3.50e-07***		
	(8.15e-08)		
Constant	3.33***		
	(0.35)		
Observations	7,758		
R^2	0.743		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

This finding may initially seem counter intuitive, but maize and teff are tradable items and with improved market access, and price information, prices may be lower in areas of higher population density.

Table 5.7: Factors Affecting Log of Maize Price, CRE SUR

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	-0.0002***	-0.0004***	-0.0006***
	(0.0001)	(0.0001)	(0.0001)
Number of cooperatives	-0.400***		
	(0.009)		
Distance to cooperative	-0.016***		
	(0.003)		
Distance to capital	-0.002***		
	(0.0001)		
Distance to a paved road	-0.007***	0.045***	0.038***
	(0.001)	(0.003)	(0.001)
Net primary productivity	0.0001***		
	(7.52e-06)		
Ten year rainfall average	-0.0004***	-0.002***	-0.002***
	(0.0001)	(0.0001)	(4.01e-5)
Elevation	-0.001***		
	(0.0003)		
Elevation^2	3.06e-07***		
	(7.71e-08)		
Constant	3.08***		
	(0.325)		
Observations	7,758		
R^2	0.74		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

This idea is supported by several market access terms, including distance from a cooperative, distance from the village to the capital, distance to a paved road, as well as the number of cooperatives in the village, all of which indicate that market access is important in determining maize and teff prices.

Table 5.8: Factors Affecting Log of Teff Price, CRE Equation by Equation

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	0.0001*** (0.00003)	-0.001*** (0.0001)	-6.99e-04*** (6.86e-05)
Number of cooperatives	-0.004 (0.007)		
Distance to cooperative	-0.008*** (0.001)		
Distance from village to capital	-3.76e-04*** (3.02e-05)		
Distance to a paved road	-0.006*** (0.001)	0.016*** (0.001)	0.010*** (0.001)
Net primary productivity	-4.78e-05*** (4.75e-06)		
Ten year rainfall average	2.69e-05 (3.73e-05)	0.001*** (5.28e-05)	0.001*** (4.13e-5)
Elevation	0.003*** (0.0001)		
Elevation^2	-5.70e-07*** (3.58e-08)		
Constant	-1.76*** (0.135)		
Observations	7,758		
R^2	0.158		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

Finally, considering agro-ecological terms, we find that net primary productivity is statistically significant with both models for both crops. This finding indicates that yields vary with soil quality. Further, it suggests that higher soil quality is associated with higher maize yield, but lower soil quality is associated with higher teff yield. This is likely a result of the two crops having different ideal conditions, and therefore the quality of soil impacts prices differently. Elevation and its square term, as well as the ten year rain average are also significant.

Table 5.9: Factors Affecting Log of Teff Price, CRE SUR

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	0.0001***	-0.0008***	-0.0006***
	(0.00003)	(0.0001)	(6.89e-05)
Number of cooperatives	-0.010		
	(0.007)		
Distance to cooperative	-0.01***		
	(0.001)		
Distance to capital	-0.0004***		
	(0.00003)		
Distance to a paved road	-0.007***	0.017***	0.009***
	(0.001)	(0.001)	(0.001)
Net primary productivity	-4.90e-05***		
	(4.83e-06)		
Ten year rainfall average	0.0001	0.001***	0.001***
	(4.06e-05)	(0.0001)	(2.03e-5)
Elevation	0.003***		
	(0.0001)		
Elevation^2	-5.70e-07***		
	(3.71e-08)		
Constant	-1.76***		
	(0.14)		
Observations	7,758		
R^2	0.52		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

Last, in Tables 5.10 and 5.11, we present the results of the log of fertilizer price equations. Overall, population density increase fertilizer price by 0.2 percent for every additional 10 people in the area. This indicates that prices increase as there are more people in a region, and increased demand for those demanding fertilizer.

Of the explanatory variables, the driving force in determining fertilizer price is location. These factors include the number of cooperatives and the distance variables, including distance from a cooperative, a paved road, and from the capital.

Table 5.10: Factors Affecting Log of Fertilizer Price, CRE Equation by Equation

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	-0.0002**	0.002***	0.002***
	(0.0001)	(0.0001)	(1.38e-04)
Female headed household	-0.006	-0.073*	-0.079**
	(0.010)	(0.040)	(0.039)
Number of cooperatives	0.196***		
	(0.021)		
Distance to cooperative	-0.028***		
	(0.002)		
Distance to capital	0.001***		
	(6.66e-05)		
Net primary productivity	7.00e-06		
	(1.05e-05)		
Ten year rainfall average	1.68e-04	-1.31e-04	3.65e-5
	(1.58e-04)	(1.98e-04)	(1.04e-4)
Elevation	-0.003***		
	(2.94e-04)		
Elevation^2	8.71e-07***		
	(7.52e-08)		
Constant	5.52***		
	(0.328)		
Observations	7,758		
R^2	0.412		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

Fertilizer prices are largely set by the government based on location, therefore the proximity of villages to roads and markets are very important. Elevation and its squared term are also significant and again emphasize the importance of location and elevation in determining prices.

These results suggest that prices are influenced by community variables, while landholding is primarily influenced by household factors. We also find that market access is of overriding importance in determining prices. As discussed earlier, population density is likely to result in improved markets and information, and therefore, it follows that markets have a great influence on purchase prices for staple crops and fertilizer, as we observe.

Table 5.11: Factors Affecting Log of Fertilizer Price, CRE SUR

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	-0.0002**	0.002***	0.002***
	(0.0001)	(0.0001)	(0.0001)
Female headed household	-0.009	-0.073*	-0.083***
	(0.010)	(0.042)	(0.014)
Number of cooperatives	0.203***		
	(0.021)		
Distance to cooperative	-0.030***		
	(0.002)		
Distance to capital	0.001***		
	(0.0001)		
Net primary productivity	9.33e-06		
	(1.06e-05)		
Ten year rainfall average	1.88e-04	-1.56e-04	3.19e-05 (4.51e-05)
	(1.54e-04)	(2.00e-04)	
Elevation	-0.003***		
	(0.0003)		
Elevation^2	8.55e-07***		
	(7.86e-08)		
Constant	5.44***		
	(0.348)		
Observations	7,758		
R^2	0.38		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

5.2.2 Fertilizer Use per Hectare

We estimate factors affecting fertilizer use per hectare in order to understand how population density and other factors drive fertilizer demand and input intensification in Ethiopia. The results for this equation can be found in Table 5.12 (equation by equation) and Table 5.13 (SUR). The latter table now includes the total effect, which can be found at the bottom, in the first column. The results indicate that population density has a

Table 5.12: Factors Affecting Fertilizer Use, CRE Equation by Equation

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	-0.002	0.195***	0.193 ***
	(0.020)	(0.047)	(0.040)
Value of assets	3.26e-04		
	(2.35e-04)		
Land lost during redistribution	1. 09		
	(3.53)		
Highest grade	0.148	-0.365	-0.217
	(0.234)	(0.799)	(0.759)
Female-headed household	-3.62*	-10.06**	-13.69***
	(2.19)	(4.95)	(4.51)
Adult equivalents	0.411	-1.73*	-1.32
	(0.431)	(0.995)	(0.89)
Recent death	-0.821	-11.04	-11.86
	(1.38)	(11.08)	(11.15)
Number of oxen	0.893	16.71***	17.60***
	(0.622)	(4.99)	(4.93)
Landholding, in hectares	-8.22***	13.65***	5.44***
	(1.50)	(2.33)	(1.52)
Fertilizer price (log)	-1.95	2.73	0.78
	(4.08)	(6.76)	(5.88)
Daily wage (log)	-0.695	-8.67**	-9.37**
	(1.36)	(4.09)	(3.82)
Teff price (log)	-8.21*	-24.47*	-32.68**
	(4.49)	(14.89)	(14.06)
Maize price (log)	-11.62*	35.57***	23.94***
	(7.07)	(8.94)	(5.60)
Distance to agricultural cooperative	-0.618		
	(0.600)		
Distance to paved road	1.00***	-3.66***	-2.65***
	(0.225)	(0.625)	(0.58)
Ten year rain average	0.085***	-0.069*	0.016
	(0.024)	(0.039)	(0.028)
Net primary productivity	-0.001		
	(0.002)		
Elevation	0.132*		
	(0.073)		
Elevation^2	-3.51e-05*		
	(1.9e-05)		
Constant	-109.60		
	(74.66)		

Table 5.12: Factors Affecting Fertilizer Use, CRE Equation by Equation (continued)

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Observations	7,758		
R^2	0.309		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

positive effect on fertilizer intensification. The direct effect of population density suggests that a 10 person increase in population density increases fertilizer use per hectare by approximately 1.81 kilograms per hectare, on average, and the effect is statistically significant at the 1% level**.** The total effect (direct + indirect effect) suggests that a 10 person increase in population density increases fertilizer use by 1.83 kilograms per hectare, on average. This finding indicates that fertilizer demand is mainly driven directly by population density, rather than indirectly through landholding, wage rates and prices. It may be that market and institutional development that happens in areas of high population density could be helping farm intensify, but this may be offset by smaller landholdings, and lower prices in these areas.

The results of the fertilizer demand equation also indicate the importance of several household and community variables. The log of daily wage, teff price, and maize price are significant determinates of fertilizer demand. Fertilizer use decreases by 9.31 kilograms for every additional percentage point increase in daily wage. Fertilizer demand also decreases by 33.97 kilograms per hectare for a 1 percent increase in teff price. Conversely, fertilizer use increases by 24.29 kilograms per hectare on average with a 1 percent increase in maize price.

Table 5.13: Factors Affecting Fertilizer Use, CRE SUR

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	-0.004	0.185***	0.181***
	(0.021)	(0.047)	(0.04)
Value of assets, in birr	0.0003		
	(0.0002)		
Land lost during redistribution	1.15		
	(3.53)		
Highest grade	0.123	-0.659	-0.535*
	(0.234)	(0.804)	(0.327)
Female-headed household	-3.61	-9.76**	-13.38***
	(2.24)	(4.77)	(2.35)
Adult equivalents	0.403	-1.602	-1.20***
	(0.434)	(1.00)	(0.37)
Recent death	-0.784	-12.53	-13.32***
	(1.35)	(11.10)	(4.91)
Number of oxen	0.888	18.28***	19.17***
	(0.622)	(5.04)	(1.87)
Landholding, in hectares	-7.91***	12.77***	4.86***
	(1.45)	(2.22)	(0.72)
Fertilizer price (log)	-4.92	4.70	-0.22
	(4.22)	(6.93)	(2.32)
Daily wage (log)	-2.06	-7.23*	-9.31***
	(1.39)	(3.96)	(1.43)
Teff price (log)	-4.93		-33.93***
	(4.50)	-29.04** (14.57)	(5.80)
Maize price (log)	1.28	23.01**	24.27***
	(8.09)	(9.45)	(2.14)
Distance to cooperative	-0.450		
	(0.588)		
Number of cooperatives	50.84***		
	(3.75)		
Distance to paved road	1.11***	-3.79***	-2.68***
	(0.230)	(0.646)	(0.28)
Ten year rain average	0.079***	-0.046	0.03***
	(0.025)	(0.037)	(0.01)
Net primary productivity	-0.003		
	(0.002)		
Elevation	0.137*		
	(0.072)		
Elevation^2	3.52e-05*		
	(1.89e-05)		
Constant	-111.61		
	(72.98)		

Table 5.13: Factors Affecting Fertilizer Use, CRE SUR (continued)

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Observations	7,758		
R^2	0.31		
Total effect	0.183***		
	(0.024)		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

All of the effects are slightly larger in the equation by equation model, although the teff price is not significant. Together these results suggests that government policy designed to increase fertilizer use would be more effective by focusing on increasing purchase prices for maize then by providing fertilizer at a subsidized price. Higher prices may increase income for households who produce more, therefore encouraging fertilizer use to expand production.

Additionally, several household characteristics have significant effects on fertilizer per hectare. First, female headed households demand less fertilizer use per hectare. On average, if a household is female-headed, 13.37fewer kilograms of fertilizer are demanded. Second, an additional adult equivalent in a household decreases fertilizer use by 1.20 kilograms per hectare. This is a relatively small effect, but suggests that large households are unable to use more fertilizer, despite having more potential labor available. This follows Figure 5.3, which suggested that higher population densities decrease fertilizer use. Third, the number of oxen increases fertilizer demand by 19.17 kilograms per hectare, on average. As households with oxen are able to use them to clear fields and prepare them for cultivation more quickly than those without, it follows such households may be more intensive in their cultivation practices, hence increasing demand for fertilizer. Finally, household landholding increases fertilizer demand by 4.86 kilograms per hectare, indicating that households with more land, also use more fertilizer.

Several community variables are also significant, including the number of cooperatives and the distance from the nearest paved road. Households in areas with more cooperatives demand significantly more fertilizer and households further from the paved road demand significantly less fertilizer. Together, these suggest that market access is important in determining the demand for fertilizer. Agro-ecological terms, elevation, and its square are also significant. This indicates the importance of location in determining the demand and the use of inputs.

5.2.3 Maize Yield

Maize is the first crop used in this thesis to examine the influence of population density on staple crop output per hectare. The results of the maize output supply equation can be found in Table 5.14 (equation by equation) and Table 5.15 (SUR). The direct effect of population density on maize yield suggests that for a 10 person increase in population density results in an additional 5.6 kilograms of maize per hectare on average. The effect is statistically significant at the 5% level. However the indirect and total effects are not statistically significant. This suggests that population density may be increasing yields through improvements in markets and information flow, but the indirect effects of smaller landholdings and lower prices offset the direct effects and make the total effect insignificant. Therefore, population density has no significant overall effect on maize yield.

Table 5.14: Factors Affecting Maize Yield, CRE Equation by Equation

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	2.60***	-1.91**	0.697**
	(0.82)	(0.82)	(0.337)
Value of assets, in birr	0.011***		
	(0.004)		
Land lost in redistribution	-46.82		
	(47.29)		
Highest grade	21.22**	-11.68	9.55
	(9.81)	(13.55)	(11.72)
Female-headed household	165.6**	-267.2***	-101.60*
	(80.22)	(96.91)	(55.77)
Adult equivalents	0.950	27.64	28.59**
	(16.14)	(19.19)	(12.37)
Recent death	78.04*	361.8**	439.88***
	(47.50)	(147.2)	(133.16)
Number of oxen	26.57	120.1**	146.66***
	(18.84)	(48.64)	(47.34)
Landholding	-19.72	-26.26	-45.98***
	(22.45)	(25.86)	(12.86)
Fertilizer price (log)	-36.33	-162.1	-198.47**
	(130.8)	(155.0)	(78.50)
Daily wage (log)	57.52	166.7**	224.3***
	(54.44)	(68.88)	(43.62)
Maize price (log)	-644.7***	1,014***	369.4***
	(187.9)	(193.5)	(33.55)
Annual rainfall	-0.063	-0.059	-0.12***
	(0.079)	(0.080)	(0.02)
Net primary productivity	0.094***		
	(0.021)		
Elevation	6.75***		
	(0.66)		
Elevation^2	-0.002***		
	(1.69e-04)		
Constant	-5034***		
	(827.7)		
Observations	7,758		
R^2	0.167		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

The results indicate that daily wages and maize price have a positive impact on maize yield. Daily wages increase maize output by 213.34 kilograms per hectare. An increase in daily wage increases income for those who participate in off-farm activities. This behavior was discussed many times in our field group surveys. Many men said that they worked off-farm when wages were high in order to purchase more inputs to use on-farm, which is likely the effect we observe here. Maize prices also increases maize yields, which makes sense, as farmers will be more incentivized to produce maize, if they believe they may be able to get a higher price at market, based on the past years' prices. Maize price increases yields by 443.78 kilograms per hectare.

Several other community and household level factors influence maize yield. First, a 10 birr increase in value of assets (about 80 cents) increases maize yield by approximately 1 kilogram per hectare. As assets are a proxy for wealth, this suggests that prosperity improves yields, although by a very small amount. Second, an additional year of schooling boosts maize yield by 12.76 kilograms per hectare. This suggests a relationship between education and yields, and that those with higher education are better farmers. Third, if a household is female-headed, yields decrease by 98.01 kilograms per hectare. This indicates that female households are not able to produce as much per hectare as their male counterparts, in addition to generally having less land, and using less fertilizer. Fourth, a recent death increases maize yield by 430.95 kilograms per hectare. This is a large effect and shows that a shock, such a death, can have a great impact on a household's production. Finally, the number of oxen owned by a household increases a household's yield by 156.01 kilograms per hectare.

Table 5.15: Factors Affecting Maize Yield, CRE SUR

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	2.63***	-2.07***	0.560**
	(0.80)	(0.81)	(0.346)
Value of assets, in birr	0.011***		
	(0.004)		
Land lost in redistribution	-28.60		
	(44.01)		
Highest grade	20.60**	-7.83	12.64*
	(10.32)	(14.22)	(6.64)
Female-headed household	155.70*	-253.83***	-98.00**
	(80.95)	(98.84)	(45.11)
Adult equivalents	0.956	31.12*	32.11***
	(16.29)	(18.84)	(6.97)
Recent death	86.04*	344.63**	430.95***
	(48.15)	(142.42)	(93.94)
Number of oxen	32.25*	123.76**	155.99***
	(17.74)	(48.76)	(34.54)
Landholding	-27.47	-22.22	-49.79***
	(22.92)	(27.05)	(13.09)
Fertilizer price (log)	-41.60	-187.33	-228.29***
	(142.93)	(162.39)	(37.18)
Daily wage (log)	106.35*	107.00	213.60***
	(56.13)	(67.94)	(25.39)
Maize price (log)	-595.91***	1,041***	444.54***
	(186.72)	(189.43)	(27.35)
Annual rainfall	-0.070	-0.042	-0.111***
	(0.084)	(0.086)	(0.015)
Net primary productivity	0.090***		
	(0.023)		
Elevation	6.82***		
	(0.631)		
Elevation^2	-0.002***		
	(0.0002)		
Constant	-5,078***		
	(808.71)		
Observations	7,758		
R^2	0.16		
Total effect	0.185		
	(0.371)		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

This follows the results of the fertilizer demand equation, and suggests that those with more oxen have higher production potential and are able to cultivate at a higher intensity. Several community variables are also significant, including net primary productivity, elevation, and its square. These suggest that better soils produce higher yields, and that higher elevations produce higher yields.

5.2.4 Teff Yield

Teff is the second crop in our study used to examine the impact of population density on staple crop output per hectare. The results for the teff supply equation can be found in Table 5.16 (equation by equation) and Table 5.17 (SUR). The results of this model indicate that the direct, indirect, and total effects of population density on teff yield are insignificant. Therefore, we can conclude that teff yield is not influenced by population density.

Several community and household level factors influence teff yield, however. Of these variables, many that were significant in determining maize output are significant in determining teff output and yield to the same interpretation. First, an additional year of schooling boosts teff yield by 15.85 kilograms per hectare. Second, the number of oxen owned by a household increases yields by 989.06 kilograms per hectare. This follows the results of the fertilizer demand equation, as well as the maize equation, and suggests that those with more oxen have higher production potential and therefore use more fertilizer and produce greater yields. Finally, landholding is significant indicating that households with more land produce less teff. This may be a result of diversification to other crops, which is possible, and potentially easier, with greater landholding.

Table 5.16: Factors Affecting Teff Yield, CRE Equation by Equation

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	-1.15***	1.14***	-0.008
	(0.22)	(0.30)	(0.237)
Value of assets	4.55e-04		
	(0.003)		
Land lost in redistribution	184.2***		
	(48.94)		
Highest grade	-10.12**	21.46*	11.34
	(5.14)	(13.04)	(11.16)
Female-headed household	-4.65	-0.922	-5.58
	(34.46)	(68.12)	(62.85)
Adult equivalents	0.512	-4.04	-3.53
	(10.21)	(15.13)	(10.47)
Recent death	-39.68	-286.8*	-326.52**
	(25.20)	(147.6)	(146.41)
Number of oxen	41.66**	1,016***	1,057***
	(17.35)	(86.44)	(81.27)
Landholding	-19.17	-8.21	-27.38**
	(15.08)	(20.95)	(12.93)
Fertilizer price (log)	-101.6	166.2	64.57
	(95.78)	(105.1)	(51.51)
Daily wage (log)	-62.89*	247.3***	184.41***
	(36.53)	(57.20)	(39.73)
Teff price (log)	133.9	-50.40	83.54
	(94.67)	(137.3)	(115.68)
Annual rainfall	0.060*	0.044	0.10***
	(0.034)	(0.039)	(0.02)
Net primary productivity	-0.058***		
	(0.016)		
Elevation	2.68***		
	(0.677)		
Elevation^2	-5.41e-04***		
	(1.73e-04)		
Constant	-3958***		
	(777.0)		
Observations	7,758		
R^2	0.321		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

Additionally, if a household lost land during redistribution influences teff yields, increasing it by 254.59 kilograms, on average. This suggests that households which lost land are now incentivized, at least for teff, to produce more if they did not lose land. This result differs somewhat from some of the previous literature in Ethiopia; this includes Ali et al. (2011) which finds that households who are tenure insecure do not make long-term investments in coffee and chat production. However, our finding is different perhaps because teff is an annual crop and other studies including Holden and Yohannes (2002), Deininger et al. (2009), and Deininger and Jin (2006) suggests that redistribution has improved access to inputs, which has increased use of fertilizer and staple crop yields. We also found in our landholding regressions that those who lost land in the redistribution farm smaller plots. Therefore, the finding of higher teff yields on plots that lost lands is consistent with the inverse productivity hypothesis, which suggests that households with smaller plots are able to produce more per hectare than households with more land. The existence of this connection has been supported by Binswanger et al. (1995), Benjamin (1995), Barrett (1996), and Lamb (2003).

Several community variables are also significant, including net primary productivity, elevation, and its square term. These suggest that better soils produce lower yields, and that higher elevations produce higher yields.

Finally, several price factors also drive teff yield. Teff price and daily wage both positively drive teff output. A 1 percent increase in teff price decreases teff output by 79.74 kilograms per hectare. Further, a 1 percent increase in daily wage increases teff yield by 184.89 kilograms per hectare.

Table 5.17: Factors Affecting Teff Yield, CRE SUR

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	-1.07***	0.976***	-0.096
	(0.226)	(0.319)	(0.263)
Value of assets	0.0004		
	(0.003)		
Land lost in redistribution	254.59***		
	(49.60)		
Highest grade	-11.35**	27.20**	15.93***
	(5.22)	(13.76)	(4.72)
Female-headed household	-13.31	10.52	-2.85
	(34.43)	(69.43)	(31.81)
Adult equivalents	-0.103	0.652	0.533
	(10.33)	(14.03)	(4.926)
Recent death	-42.64*	-213.21	-255.98***
	(25.96)	(138.36)	(66.03)
Number of oxen	39.12**	949.95***	989.07***
	(17.26)	(84.29)	(23.99)
Landholding	-40.87***	12.99	-27.82***
	(15.74)	(20.74)	(9.22)
Fertilizer price (log)	-41.88	155.57	113.39***
	(94.06)	(102.20)	(26.58)
Daily wage (log)	23.26	162.08***	185.14***
	(39.46)	(57.93)	(18.56)
Teff price (log)	322.05**	-402.56***	-79.74*
	(134.23)	(141.40)	(67.17)
Annual rainfall	0.062*	0.094**	0.160***
	(0.035)	(0.042)	(0.011)
Net primary productivity	-0.083***		
	(0.016)		
Elevation	2.96***		
	(0.717)		
Elevation^2	-0.001***		
	(0.0002)		
Constant	-4,648***		
	(849.13)		
Observations	7,758		
R^2	0.31		
Total effect	-0.330		
	(0.302)		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

It is intuitive is why an increase in daily wage increases teff output, as an increase in daily wage increases the income for those who participate in off-farm activities, allowing them to purchase more inputs or invest more in their own farms. However, the relationship between teff price and teff production is not altogether intuitive, as farmers are not incentivized to produce teff for potentially higher prices. This does suggest though that while prices have a relationship with production, people will generally produce teff regardless of price, in the long-run.

Considering the maize yield results and teff yield results, three differences do exist. These differences include: 1) whether a household is female-headed does not influence teff output (it had a negative effect in the long-run); 2) land lost in redistribution has a positive effect on teff output (it did not influence maize output); and 3) whether a household had a recent death in the household has a positive effect on maize output (it had no impact on teff output). However, these differences result from the fact that maize and teff are not perfect substitutes for one another, and therefore have relationships with slightly different factors, despite having many similarities.

5.2.5 Farm Income per Hectare

Finally, farm output per hectare is used in our analysis to understand the effect of population density on overall farm productivity measured by the value of crop output, including staple crops and cash crops, as well as output of farm animals. The results for the farm output equation can be found in Table 5.18 (equation by equation) and Table 5.19 (SUR). While the time average of population density is statistically significant and negative, neither the direct effect nor the total effect, which can be found at the bottom of the table, is significantly different from zero.

Table 5.18: Factors Affecting Farm Income, CRE Equation by Equation

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	553.3	-641.8***	-88.51
	(343.6)	(245.8)	(151.44)
Value of assets	-1.25		
	(1.13)		
Land lost in redistribution	-78,586		
	(55,984)		
Highest grade	27,345	1,204	28,549
	(31,890)	(10,974)	(24,041)
Female-headed household	-10,400	133,604	123,204
	(14,095)	(127,394)	(127,165)
Adult equivalents	63,940	-54,369	9,571
	(78,317)	(70,269)	(8,740)
Recent death	-87,158	207,071	119,913
	(83,796)	(198,003)	(115,770)
Number of oxen	143,762	-117,878	25,884
	(114,515)	(86,062)	(38,815)
Landholding, in hectares	-66,770**	30,035	-36,735***
	(31,766)	(25,414)	(13,025)
Fertilizer price (log)	-2,253	-135,386***	-137,638***
	(16,668)	(49,571)	(42,987)
Daily wage (log)	-27,361	-36,994	-64,356
	(53,884)	(43,540)	(62,807)
Teff price (log)	115,128	-37,731	77,397
	(105,727)	(139,663)	(234,631)
Maize price (log)	109,317	-105,511	3,806
	(86,972)	(107,052)	(24,118)
Annual rainfall	38.30	-81.42	-43.11
	(44.97)	(50.08)	(41.37)
Net primary productivity	29.48		
	(19.55)		
Elevation	63.98		
	(419.7)		
Elevation^2	-0.031		
	(0.089)		
Constant	680,520		
	(611,551)		
Observations	7,758		
R^2	0.012		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

Therefore, we can conclude that overall population density does not significantly drive farm income. The only factors which influence farm income per hectare are the landholding of the household and the log of fertilizer price. Landholding negatively influences farm output per hectare by 68,099 (about 5,000 dollars) for every additional hectare owned. The effect is slightly larger in the equation by equation model. Further, fertilizer price drives down income by 130,147 birr (about 1,000 dollars). This relationship indicates that farmers are unable to produce as crops as successfully, with higher prices of fertilizer, and as a result farm income declines. These are both large effects and suggest that income is highly responsive to landholding and fertilizer price, despite having no impact on so many other regressors.

Table 5.19: Factors Affecting Farm Income, CRE SUR

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Population / land	526.62	-610.74**	-84.11
	(336.99)	(245.05)	(166.36)
Value of assets	-1.31		
	(1.21)		
Land lost in redistribution	-70,770		
	(46,741)		
Highest grade	27,495	1,245	22,664
	(33,171)	(11,611)	(7,491)
Female-headed household	-10,927	132,175	126,653
	(15,605)	(131,840)	(54,957)
Adult equivalents	63,980	-53,947	11,090
	(81,036)	(71,752)	(8,506)
Recent death	-87,368	211,808	139,622
	(86,690)	(209,104)	(114,249)
Number of oxen	143,786	-123,895	16,918
	(119,417)	(96,541)	(42,086)
Landholding, in hectares	-68,099**	30,774	-41,556***
	(34,170)	(26,512)	15,730
Fertilizer price (log)	-25,065	-130,148**	-102,716**
	(22,984)	(53,754)	(42,698)
Daily wage (log)	-18,992	-45,343	-45,580
	(49,143)	(51,109)	(30,787)

Table 5.19: Factors Affecting Farm Income, CRE SUR (continued)

	Time-Varying Covariate	Time-Average Covariate	Joint Direct Effect
Teff price (log)	133,589	-83,911	-64,408
	(195,771)	(97,524)	(112,216)
Maize price (log)	24,702	-24,052	13,125
	(44,064)	(47,127)	(32,940)
Annual rainfall	38.30	-76.91	-41.50
	(51.02)	(55.75)	(54.40)
Net primary productivity	26.67		
	(19.75)		
Elevation	13.29		
	(592.11)		
Elevation^2	-0.015		
	(0.134)		
Constant	774,934		
	(811,312)		
Observations	7,758		
R^2	0.01		
Total effect	-160.05		
	(128.11)		

Note: ***, **, * denotes that the corresponding coefficients are statistically significant at the 1%, 5% and 10% level respectively; standard errors in parentheses. Year dummies are also included.

CHAPTER 6: CONCLUSIONS

6.1 Summary of Findings

The objective of this thesis is to estimate the impacts of population density on agricultural intensification and farm income in Ethiopia. We first evaluate the direct channels through which population density impacts intensification, measured as fertilizer demand per hectare, maize and teff yields, and farm income per hectare. Population density directly influences agricultural intensification by improving information flows, enabling the development of institutions, and reducing transactions costs. In addition, we estimate the indirect effects that population density has on intensification and income through its effect on landholding, wage rates, fertilizer prices and maize and teff prices. Dramatic increases in population density and corresponding difficulties in access to land suitable for agricultural activities are prevalent throughout Ethiopia. This thesis finds that population density is a significant factor that influences input demand, but not output supply.

The main findings of the study are as follows. First, we find that increased population density lead to smaller farm sizes. This has major implications for staple crop production and household food security, as it limits farm productivity on the extensive margin. This suggests that developing a functioning land market, by permitting people to sell and rent land may boost productivity. A working land market would encourage those who would rather leave agriculture to sell or rent land to those who can use it more productively.

Additionally, we find that population density has a positive effect on input demand, represented by fertilizer use per cultivated area. We find that input intensification is driven by the direct effects of population density, including improved information flow, institutions, and reduced transaction costs, rather than through the indirect effects of factor prices and landholding. We are also able to conclude that population density has no significant relationship with maize yield, teff yield, and farm income.

Finally, we find that maize and teff prices fall when population density suggesting that in more densely populated regions there may be better market access and improved information. Since staple crops are tradable goods, as markets develop commodities move to areas of higher demand.

In addition to these direct effects of population density intensification and well-being, we find that market access factors such as distance to cooperatives and roads have an effect on output prices, and fertilizer demand. Therefore, improving infrastructure is an important policy measure to reduce transaction costs, as well as the cost of fertilizer and prices of staple crops. Education is also of great importance and the positive relationship between higher education attainment, fertilizer use, and yields suggests that school systems should be expanded and supported.

Finally, this study finds that past land redistribution practices may have influenced present investment patterns. We find that, at least in the short-term, people produce more teff, if they previously lost land. This follows perceptions of farmers from our field group discussions who believe that past losses increase present productivity. As we also found that farm size is negatively influenced by population density, these effects combined suggest evidence of the inverse productivity hypothesis, indicating that smaller farms are able to produce more per unit of land (Binswanger et al., 1995, Benjamin, 1995, Barrett, 1996, Lamb, 2003). These two effects are connected as farmers that lost land historically, and still have some anxiety about losing land again, may invest more in short term annual crop production to get what they can out of their land in the short term compared to farmers who did not lose land in the past.

The overall picture which emerges from this thesis is that population density is an important driver of intensification of agricultural practices in the context of rising densities across Ethiopia. While this thesis is not the first to acknowledge this issue, to our knowledge, it is the first to use panel data to quantify the impacts of population density and the influence that it has on landholding, wage rates, staple crop prices, agricultural intensification, productivity, and farm income. Results from our study indicate that in Ethiopia households tend to use more fertilizer to intensify production at higher population densities. It is not clear if development strategies focused on intensifying agricultural productivity through fertilizer use will be enough to overcome Ethiopia's issues of land access, food security, and poverty, alone. However, it is important that steps be taken to mitigate rising population and growing constraints on smallholder farmers before it is too late to address these issues.

6.2 Policy Implications

Despite a relative abundance of land, Ethiopia is dominated by densely populated regions and progressively smaller farms. While a comprehension of these problems, and incorporation of the resulting issues into national development plans and poverty reduction strategies, we also make several policy implications based on the relationships between population density, input demand, and output supply. Therefore, we make the following policy recommendations:

1. Agricultural wages are increased by higher population density. Therefore, people who desire to work off-farm should be incentivized to migrate to places where they can obtain higher wages. Programs to encourage such migration could be successful not only in improving employment, but also potentially increase staple crop yields. Location of demand and supply, in terms of jobs and people willing to work, are also important to consider.
2. Population density also leads to smaller landholding. Developing a functioning land market, through permitting people to sell and rent land may boost productivity. A working land market would encourage those who would rather leave agriculture to sell or rent land to those who can use it more productively.
3. The distance to a cooperative, the distance to a paved road, and the distance from the capital often influence prices and yields. Therefore, improving infrastructure and ensuring development of markets is an important policy measure to reduce transaction costs, as well as the cost of fertilizer and prices of staple crops.
4. Short-term production behavior is positively influenced by historic redistribution and resettlement practices. However, redistributions have negatively influenced farm sizes; making the landholding of those who lost land in 1995 smaller today. These two effects are connected as farmers that lost land historically, and still have some anxiety about losing land again, may try harder in the immediate term

than they might otherwise. This mentality may result in the soil being overused as farmers try to get all that they can today, on typically smaller plots of land. Future redistribution and resettlement programs should keep these effects in mind, as it could influence future productivity, even if it has been beneficial thus far.

5. Net primary productivity influences staple crop prices and daily wages and hence it is important to consider soil quality. The government should undertake and support soil management programs in order to preserve current soil conditions, and potentially improve them over time. These could include soil terracing, increased incentives for fallow periods, crop rotation, or tillage.
6. Education is of great concern to many farmers. Increases in education are associated with higher landholding, increased daily wage, increased demand for fertilizer, and increased output per hectare of maize. Further, adequate access to education was of tremendous concern in many of our focus group discussions. Parents generally believe that their children will be better off with more education, and are concerned about their futures if they are unable to access it. Therefore, continued and increased access to quality education is of huge importance for the future of rural farmers, particularly as population density continues to expand.

It is not clear if these strategies will be enough to overcome Ethiopia’s issues of land access, food security, and poverty, on their own. However, it is important that steps be taken to mitigate rising population and growing constraints on smallholder farmers before it is too late to address these issues altogether.

6.3 Limitations

Although this research is carefully prepared, we are aware of its limitations and shortcomings. These issues cannot be easily addressed and primarily focus on the data used for then analysis.

1. The panel is relatively short, covering only 11 years. Issues of population density have long-term influence, and though we attempt to uncover these long-term effects in our analysis, the period analyzed is still relatively short.
2. There is limited spatial variation across villages. As the ERHS only considers 15 villages, there are only 90 distinct observations for population density (15 villages over 6 years). This limits conclusions which can be made regarding population density, despite the observed variation across the 15 villages.
3. The data is not nationally representative, as non-pastoral households are not considered. Widening the sample to be nationally representation would allow the development of broader conclusions and therefore potentially improved policy implications.
4. Other potential measures of intensification and productivity are not considered. In particular, hybrid seeds, on-farm labor, mechanization, and crop diversification are not evaluated in this thesis. This is primarily due to their absence in the ERHS survey and desires to limit the scope of this thesis.

These limitations give way for excellent future research, and the potential to expand conclusions and policy implications based on such improvements.

6.4 Future Research

Future research on this topic should take advantage of the existing conceptual framework, but build upon the limitations mentioned previously, in order to address issues with data. Most importantly, the use of a longer, more nationally representative panel, with a greater variation in population density locations could tremendously improve the strength of our conclusions. Further, expanding the definition of intensification and productivity would be effective for a broader evaluation of the problem. This reframing of the problem, using a different data set, could serve to test the robustness of our conclusions.

Further, our econometric method could be improved or expand through the use of other estimators, such as a 3SLS or GMM. This would be done in conjunction with a re-specification of the model in a recursive fashion, rather than the current non-recursive version we have used thus far. With the current specification it is difficult to find exclusion variables; however, there is opportunity for the design of a recursive model.

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APPENDIX

APPENDIX: FOCUS GROUP DISCUSSIONS

A.1 Debre Birhan

Debre Birhan is located 120 kilometers northeast of Ethiopia's capital, Addis Ababa. As it is situated at the center of the highland plateau Shewa, the town serves as an important economic of political center for the surrounding peasant communities. The main crops grown in the area are teff, barley, and beans, all of which are grown for household consumption. Using local varieties, maize and wheat are also grown, using hybrid seeds. Hybrids over traditional seeds are preferred for these crops as they generate higher yield and are "more clean"[9] when harvested. However, in recent years, hybrid seeds have begun to fail and lose productivity due to changes in the formula which make them inappropriate for the type of soil in Debre Birhan.

The primary problems faced by farmers are: 1) decreasing soil quality and 2) decreasing land access. Issues with soil quality are exacerbated by steep topography. Due to lack of space, farmers are forced to cultivate on slopes, which causes erosion, and results in further degradation of the soil. Continuous cultivation and clearing of trees have also become common practice, in order to increase available land for farming, both of which contribute to the decreasing quality of the soil. These issues have become more

[9] While this is a quote from our discussions, we assume that they are referring to the final crop, and the easy of cleaning the final product for sale and consumption.

problematic due to increases in population and connect with decreasing access to land. With increasing population density, land has become scarce due to large numbers of people wishing to farm in the same amount of space. While some common land remains, it is used for grazing and pasture land and is not available to transition to household farm land. Farmers are eager to obtain more land, but do not believe that this is possible, as there is no land that is not being used for agricultural purposes at this time. Further, there is general fear of land redistribution occurring again in the region within the next ten years, generating a feeling of tenure insecurity.

Land redistribution is a large issue within the community. Debre Birhan has gone through the process of land registration, which gives families a clear claim to their land, but these certificates indicate that the government has the right to seize and redistribute land at any time, without warning. As a result, people do not feel secure in their tenure, although farmers do not believe that this decreases their productivity. One farmer indicated that "…the land may belong to the government…but with that in mind, the land belongs to me."

In addition to issues of soil quality and decreased land access, weather is a constant problem. While rainfall is generally regular and good throughout the rainy season, Debre Birhan has experienced crop destruction due to snow and hail, both of which are somewhat uncommon in Ethiopia. Due to the steep topography of the region, farmers are used to dealing with flooding due to excessive rain, but they are wholly unable to deal with it. Hail, in particular, destroys crops and farmers are unsure how to deal with it. Farmers often mentioned climate change, and hold it responsible for changing weather patterns.

As a result of the change weather, soil, and decreasing land availability farmers are not optimistic about the future. While they feel that children should attend school, they do not believe that children who do will hold better jobs than themselves, and for the most part believe that their children will also be farmers. While they feel that education will help their children to become better farmers, due to lack of nearby private schools, and poor quality of local public schools, they are not confident this will actually be the outcome.

A.2 Dinki

Dinki is located in the northern region of the highland plateau Shewa northeast of Addis Ababa. It is a fairly isolated village; the closest city is Ankober, approximately 20 kilometers away. Due to its isolation, Dinki suffered greatly during the 1984 famine. The main crops grown in the area are teff and millet, although diversification to more crops is prevalent, particularly to high value crops. Hybrids seeds are commonly used for maize and teff, although hybrids are only preferred for the latter. As hybrid seeds require more water and fertilizer, and Dinki is a particularly hot area, such seeds can be difficult to keep alive. While outputs have improved in the past several years, there is still not enough surplus to sell to the dealers who frequent the area

The primary problems faced by farmers include: 1) access to land, 2) decreased soil quality, and 3) pest damage. Farm sizes are shrinking, due to increases in population density, with the average person holding about three quarters of a hectare. Due to rising population density, all land has been transitioned to agricultural land, save for a mountain, which is not possible to farm or to use for grazing, due to its extreme slope.

Farmers indicate that they would like more land to farm, but due to no close-by clear land, they do not believe such a possibility exists. The lack of land is made more problematic by the poor quality of soil. Farmers feel that the poor soil quality makes their land seem even smaller. Erosion and repeated farming are responsible for the degradation of soil quality, both of which are caused by the lack of available land to farm. Farmers treat poor soil quality with increased use of fertilizer, although the price of fertilizer has now risen to a point where it is not possible for most farmers to afford. As a result, the yield of many crops has decreased. Yields are also lowered due to problems with pests. Worms and monkeys are particularly problematic. Worms, which have become a problem only in the past ten years, often eat crops while they are young. Farmers are sometimes able to replant and start the crop again when this occurs, but they are unsure of how to eliminate the worms altogether. Additionally, monkeys are a larger problem, as they steal fully grown plants, which farmers are not able to replant in time.

In recent years, weather has also become a problem. Farmers again cite climate change as the cause of the shift in weather patterns which they are unable to accommodate. In Dinki, climate change is manifested primarily through regular drought. While historically Dinki, like most regions of Ethiopia, has experienced two seasons of rain, in the past five years rainfall has decreased. The first rainy season has been lost altogether and the second is delayed. In an already hot and dry climate, this caused problems for crop yields, as well as for herders who require water for their animals.

Despite a history of famine and rising concerns about drought, many farmers are optimistic regarding the future. Farmers are eager to diversify crops and to move away from simply growing staples for consumption to growing high value crops for sale.

Further, many feel that despite their current isolation, over the next several years, more roads will be put in and electricity will come into the area, modernizing the whole village. However, despite this optimism about their town, most farmers do not believe that their children will have good lives, if they decide to be farmers. Due to decreasing farm size, general lack of land, and declining crop yields, farmers indicate that they would like their children to work in other professions. By sending children to school and encouraging children to migrate to larger urban areas, people believe that their children will have better lives. Therefore, many parents encourage their children to attend school and ultimately migrate to Addis Ababa or to the Middle East.

A.3 Sirbana

Sirbana is located in the Shewa province, southeast of Addis Ababa. The village is located by the main road which connects Addis Ababa, to Debre Zeit, one of the larger cities in the country. Due to the proximity of the village to two large cities it is quite wealthy and has been historically targeted with agricultural policy by the government. The primary crops grown are permanent crops and cereals, with teff being particularly successful in the region. The area has good soil and hybrids are generally successful and preferred by farmers. As hybrids generally lead to higher yields, and are also disease tolerance, and weed resistance, most farmers use hybrids whenever available.

The primary problems faced by farmers are: 1) lack of access to fertilizer, 2) land scarcity, and 3) lack of adequate education. As all farmers prefer hybrid seeds to conventional seeds, and hybrids require fertilizer to be successful, fertilizer is essential. However, fertilizer is often unavailable, or too expensive. There are also problems with timing of fertilizer delivery, as often it comes too late to be used. Therefore, while farmers have been able to somewhat head off the increasing land scarcity in the area, the lack of access to fertilizer has increased the problem. The drastically increasing population the area, exacerbated by large in-migration, has increased issues with adequate access to land. Most individuals hold approximately one half of a hectare. With such a small area of land, fallow practices have been eliminated, and many individuals have moved away from planting cereal crops for consumption to growing chat and coffee for sale, effectively becoming net purchasers of food. Many find that this also mitigates issues with fertilizer, because tree crops do not require annual fertilization. However, it does not increase food security, and many feel that though they have good land, and good soil, they are unable to make enough food to survive simply because they do not have enough space.

Many farmers also expressed concerns with education. Due to changes in government policy, the education which adults attained in school is quite different from what their children are now learning in the same schools. The largest difference is that school is now taught in a different language[10]. As the parents are only able to speak the new language, but cannot read the characters, many children struggle and drop out before they would if their parents were able to help them. Parents often hire a tutor for their children, but it is very expensive to do so. With a great understanding and appreciation of the importance of education, parents are very nervous about the prospects for their children, if they are unable to complete grade school.

[10] During the Derg, all schools taught Amheric, the national language in Ethiopia. Under the new federal democratic republic, states are encouraged to teach regional languages and letters. As a result, this region now learns Oromifa in school.

The central location of Sirbana encourages investment from foreign companies interested in growing vegetables and cut flowers for sale abroad. A recent large scale investment from Holland brought 2,000 jobs to the area, which people were able to obtain without high school or college education. Some farmers gave up their land in order to work at the factory instead. However, despite the benefits from the jobs, the company also diverted water away from farmers, causing problems for subsistence farmers. Further, those who worked in the factory were exposed to chemicals which caused subsequent health problems. While many farmers feel that the best path for the future is to work off-farm to earn money, and to keep a small farm in order to grow food for consumption, issues such as water diversion and health problems caused by large scale investments have made many wary of any type of foreign investment.

Due to poor past relationships with education and investment, most farmers are not particularly optimistic about the future of the community, although they are optimistic about the future of their children. Many believe that education opportunities will decrease and foreign investment will increase, exacerbating the issues of land and problems with chemicals which they have already experienced. Overall, most farmers hope that their children will also be farmers. Many believe that the large investment farms will teach them about technology, and therefore their children will learn to improve their farming techniques. However, while they feel that their children will be better off as adults, they do not think that they themselves will be better off in their own lifetime.

A.4 Korodegaga

Korodegaga is situated in Oromia located southeast of Addis Ababa. It is a poor-soiled, located in an impoverished region, just outside of a fertile and wealthy valley. The village is bordered by the Awash River, and the only access to the village is on a raft, manually hauled across the river on a steel cable. Korodegaga is remote, 38 kilometers from the nearest paved road, which results in many issues related to access, in particular in regard to buying and selling food. Cereals are the most common crop, but in recent years some households have grown green beans for sale at market. Hybrids are occasionally available, although seeds are frequently delivered too late to use. This is likely the result of Korodegaga's distance from markets. Although the town is located on the river, drought is a large problem in the region. As most hybrid seeds are resistant to drought they are preferred over local varieties.

The primary problems faced by farmers include: 1) lack of access to roads and markets, 2) poor soil quality, and 3) land scarcity. Due to the town's isolation, residents of Korodegaga have frequent issues with late delivery of seed and fertilizer, and are therefore often unable to use them. Also, due to the distance from markets, when traders come to the region, they drop the price at which they are willing to buy, and hence if farmers sell crops, they do not make a profit. Poor soil quality makes the absence of fertilizer and hybrid seeds even more problematic. Poor soil quality has resulted in lower yields in recent years. The decreased soil quality is largely due to erosion and deforestation which resulted from clearing of land to make the area more suitable for agricultural purposes. Land scarcity is the largest problem, however. With rapidly increasing population and barriers to out-migration, more people are demanding land for farming in the region. Large estate farms have also come into the area, increasing competition for land, though thus far estate farms have been unsuccessful due to the poor quality of soil. On average, farmers own just less than 1 hectare of land, although all expect this amount to decrease in the next five years.

Women are particularly outspoken in the community, compared with other regions in Ethiopia. Women believe that ownership of their own reproductive decisions could help to mitigate population growth, but they did not feel that they have an understanding of contraceptive to a point where this was possible. As a result they felt that land would be a greater problem over time due to more children to split the land among. Further, they felt somewhat that this densification was their fault.

Weather is also a large problem in the region. While on a river, drought is a great issue. Irrigation cannot always be done, although most farms to have the capacity to do so. While there is a pipe in the village that leads to farms, it is too expensive to pump water from the river to irrigate fields. Drought is a particularly large problem during the planting season, while flooding is a problem during the harvesting season. Further, during the rainy season, the river often overflows, and destroys crops which are farmed along the river and otherwise benefit from the water's proximity. Water in general is an issue in Korodegaga, as many farmers have problems with drinking water, in addition to water for farming. All water is obtained from the river, but the river is polluted by a nearby recreation center. As a result, there are problems with water beyond the drought and flooding dealt with by farmers in other areas.

Despite their difficult situation, all farmers, particularly women, feel that the future will be better for their children. Due to technology, modern inputs, increased planting and growth of high value crops, and better education for their children, farmers believe that their children will be better off, regardless of their chosen profession. Many farmers feel that they will be even more successful if a road is built to the area.

A.5 Oda Dawata – Assela

Assela is situated in the Oromia region, southeast of Addis Ababa. It is located at the base of a set of hills, although most of the land within the village is flat. The primary crops grown are wheat, maize, and barley. Hybrids are preferred by most households as they generate greater yields and are more tolerant to disease than local varieties. Many vegetables are also grown, including potatoes, onions, and beans, although only local varieties are used. Traders do not frequent the region, although there is a market close-by where farmers can sell their surplus. In recent years, farmers have grown more potatoes due to increased demand at market. Many farmers have found that growing a few potato plants can ensure money for food, even if other crops fail.

The main problem faced by farmers is lack of access to land due to rising population density in the region. Although Assela does not deal with the same problems of lack of access to fertilizer and seed, or soil degradation as observed in other areas, most farmers perceive a tremendous increase in population density. In addition to more people having more children, there are also fewer people migrating out of the area, and more people immigrating into the region. There is a general perception that farmland is better in this region and therefore people are hesitant to leave, and many people are eager to come. As a result of the increase in population, land has become scare. Most people own about 1 hectare, although some in the area own as many as 7 hectares. As a result of the decreasing availability of land, fallow periods have become uncommon and alternative land management practices have become popular. Many people favor crop circulation and manure to restore land.

Rain is also a concern, primarily due to flooding. As the village is located below hills, drainage off the hills, in addition to the rain itself, often damages crops. Also, although the nearest market is not far, it is necessary to cross a bridge to get to it, and in strong rains, the bridge is often washed away. Farmers have observed that rain has become much stronger in recent years, and although its frequency has not changed, the amount of rain that comes each season has increased. Many farmers attribute this shift to climate change.

Opinions about the future are consistent between farmers. Some felt optimistic about the future, while an equal number were pessimistic. For those who were optimistic, they trusted that science and technology would help children to improve farming. They also believed that children could advance into different professions with more education. They felt that their children would be as well off as themselves, and in most cases, potentially even better off. However, while those who were pessimistic agreed that education and technology would improve the lives of their children, they believed that rising food prices and increased costs associated with farming would make it too difficult to have a living in any type of work. As a result, they felt their children’s lives would be worse than their own. Both groups agreed, however, that in the future, farms would be smaller and that any adaptations in farming practices would need to come through technology. Further, both groups felt that rather than attempting to deal with the issue of lack of land, over which they have no control, they should instead try to family plan, and have fewer children to address land scarcity. Further, they also felt that diversifying into more off-farm activities, in particular handicrafts would be a good route for their children in the future, when farming became more difficult.

A.6 Turphe Kechema

Turphe Kechema is situated in the eastern Shewa zone of the Oromia region, close to the relatively large city of Shashemene, southeast of Addis Ababa. Located about approximately 2,000 meters in elevation, it is a plain area with fertile soil suitable for agriculture. Further, it is in the vicinity of one of Ethiopia's large forests, as well as to three rivers, one of which runs through the village. The primary crops of the area are wheat, barely, teff, and potatoes, although maize and chickpeas are also grown. Hybrid seeds are only preferred for wheat and maize, as for other crops using hybrids historically resulted in crop failures.

The primary problems faced by farmers are: 1) soil quality and 2) access to land. Soil quality has been decreasing over the past twenty years, and few measures have been taken to mitigate the decline. Inappropriate farming techniques, in particular elimination of fallow periods, and deforestation have caused soil quality to deteriorate. The problem has been exacerbated by lack of access to fertilizer, which is too expensive for most farmers in the area to afford. The poor soil quality, combined with lack of access to land, has caused many people to leave farming altogether and become day laborers in Shashemene, a large city nearby. Despite people leaving farming, there is still a lack of land, and most farmers own just less than 1 hectare. Some common land still exists in the village, although this is primarily used for animal grazing. Animal agriculture has become more common in Turphe Kechema as population density has increased, as animals do not require as much land as required by food crops.

Registration activities recently took place in Turphe Kechema and they have increased security of land ownership. Farmers now feel as though they actually own their land, although they do understand that the government is still technically the legal owner. Most farmers also believe that registration has resolved disputes that previously occurred as the boundaries of property are more clearly defined. Unfortunately, taxes are now more clearly established, and the amount paid is based on the amount of land held. Farmers enjoy having clear boundaries, but do not care for paying taxes. However, they believe on the whole that the registration program was successful.

Farmers do not have a positive opinion of the schools in the area. Most feel that 20 years ago, when they were going to school, education was far better. Due to the increase in competition for jobs and the increase in the average level of education of a typical person, a high school or college education no longer guarantees a job. As a result, many farmers believe that education is worth less than it was previously. However, although they do not believe that education has a great value, most farmers also do not believe that their children should be farmers. As landholding is decreasing and prices of food are rising, most farmers believe that their children should seek other professions, outside of farming.

Since farmers do not believe that farming or education will improve the lives of their children, they feel that they must save more money for them. Many with older children have also encouraged migration beyond Sheshamane to Addis Ababa and the Middle East. For those that remain in the area, farmers believe that diversification of crops, away from plants, to animals, will be a good decision for the long-term. Goats, particularly, are easy to care for and do not require much land. However, overall, most farmers believe that moving away from the area altogether will be the best option for success.

A.7 Addado

Addado is located 390 kilometers south of Ethiopia's capital, Addis Ababa, in the Gedeo zone of Southern Ethiopia. The two largest towns nearby are Bule, which is 10 kilometers away, and Dila, which is 25 kilometers away. Due to its isolation, the people of the Gedeo zone have been historically considered culturally and linguistically different than the rest of the population. However, in recent years, improved transportation has decreased this diversity. The region is known for its excellent production of coffee. Unfortunately, there has been general lack of success in growing cereals. While some maize hybrids are grown in the region, for the most part, enset is the staple crop of choice. Enset is a perennial tree crop, which produces a starchy root vegetable, which resembles a banana. Throughout Ethiopia, it is generally considered to be a food of desperation, eaten only during times of starvation. As a result of Addado's historic isolation, most farmers do not to rely on markets for staple crops, and instead grow enset to ensure food security.

The primary problems facing farmers include: 1) soil degradation and 2) access to land. While most of the crops grown in the area are tree crops, which do not require fertilizer or the same level of soil quality as subsistence crops, soil quality is still problematic for those who grow subsistence staple crops. As mentioned previously, many families move away from subsistence crops to coffee. Lack of access to land is common due to the success of coffee in the region as well. Many large scale investors have built coffee plantations, which create jobs for local people, but take away land from small-scale farmers.

In addition to large estate farms, a great increase in population has made land even more constrained. Some farmers have left farming and instead diversified into other activities, including working as hired labor on other people's farmers, self-employment making handicrafts, as well as working in coffee-trading. While coffee-trading is quite common in the area, most traders are not local, and historically locals who have tried to make their living this way have not been successful.

Education is a large concern in Addado. Though all adults believe that education is important and want their children to go to school, attendance at primary school is below 40 percent, and no children attend secondary school. Parents feel that it is difficult to force children to attend school. Paying for education and the quality of the schools in the area are also of concern to many farmers. With so many local coffee plantations, there are many opportunities for off-farm labor even for children. Therefore many children leave school in order to make extra money for their families. In a community where food is scare, and generally purchased rather than grown, it is difficult for parents to force their children to attend school when they could be making money. One teacher expressed concerns of this problem and admitted that he did not know how to begin to address the problem.

Perhaps due to the status of education in the community, many farmers believe that the future will not be better for their children. Even those who hold the most optimistic view of the future still only feel that their children's lives will be fine. They feel that their lives are already decent, so it is likely that is how circumstances will continue. For those farmers who are not optimistic, it seems that there is not enough land, there are too many people, and these pressures will combine to make life too difficult for everyone. Instead of farming, most believe that children should seek employment away from the village, toward the capital or other large cities in Ethiopia. Some families even express the desire to move away from the village while their children are still young. They hope that will give them the chance to get an education and live somewhere else, so and ensure that they do not get stuck in Addado, which they view as entrenched in poverty.

A.8 Aze Deboa

Aze Deboa is situated about 360 kilometers southwest of Addis Ababa and is about 4 kilometers from Durame, the next closest city. The woreda[11] in which it is located, Kembata, is one of the most densely populated in Ethiopia. Due to the proximity to so many cities, the region has a long history of seasonal and temporary migration. Most crops, as a result, are primarily tended by women, who are present year-round. These crops include enset and maize for consumption, as well as chat and coffee for sale. Hybrids are preferred for maize, however, recently yields have decreased and many farmers are shifting away from hybrids altogether. When growing hybrids, fertilizer is essential. As fertilizer has risen in price, recently it has been too difficult for farmers to purchase, further encouraging farmers to return to conventional varieties of seeds.

The primary problems faced by farmers include: 1) lack of access to land, 2) soil degradation, and 3) climate change. Access to land has decreased due to increases in

[11] This is an Ethiopian word that is the English equivalent of county.

population density. Most farmers now hold approximately ½ of a hectare, while twenty years ago, most farmers owned 2 hectares. Some common land is still available in the village, although it is used for grazing. Many farmers wish the land could be divided among those who do not have any land. Population density expansion has also resulted in the degradation of soil, due to over-farming and deforestation of land in order to create land suitable for agriculture. While some practices, including soil ditching to prevent water retention and planting trees to restore soil quality, have been undertaken in recent years, the effects of such practices have not yet been observed.

Climate change was highlighted and frequently discussed by farmers as it influences all areas of their lives. Farmers attribute many problems to climate change, including: 1) soil degradation, 2) decreasing yields, and 3) shifting weather patterns. The last of these points is largely observed through changes in seasonal rains. The timing of rain has shifted so there are more droughts during the first rainy season and more flooding during the second rainy season. When drought occurs, the land becomes dry, which results in greater flooding when the rains do come. Flooding causes erosion and washes away crops, which further damages soil. Additionally, dry weather followed by flooding encourages the growth of pests, particularly on root crops, ultimately killing them. Farmers believe that in the future, climate change will become worse, and they are not sure how to adapt to it.

In the future, most farmers hope that circumstances will improve. However, when they consider climate change and population pressures, they do not believe that their lives will get better. Most feel that if they or their children want to remain working as farmers, they will need to transition away from growing staples crops, and instead move totally toward high value crops, such as beans, coffee, vegetables, and root crops. Even with these changes, however, they do not believe that their children will have lives as good as their own, if they continue working as farmers. Instead parents believe that their children should look for local non-farm employment, in particular in making handicrafts and similar artisan crafts. They also believe that migration out of the area, into larger urban areas, or more fertile rural areas, would be more productive than staying in the area. As migration for seasonal purposes is very common in the region, most parents feel that for their sons, long-term migration is a natural choice.

A.9 Doma

Doma is situated about 500 kilometers south of Addis Ababa and 100 kilometers from Sodo, the capital of the region. Most residents of Doma were resettled into the area during the 1980s, in an attempt to move people away from areas suffering from drought during that time. Although Doma[12] means “harshlands” and from 1985 until 1990 the area suffered a drought, most households resettled into the area have remained. The soil is fertile and not particularly densely populated. The most common crops grown are enset and maize, with maize planted primarily as a hybrid crop. Fertilizer has only begun to be used within the last fifteen years, as the quality of soil began to decrease. Historically both soil and seeds are received at the appropriate time, although recently delivery has been later, and not on time. Farmers believe that because they have been resettled into the area, the government makes sure that they have seed and fertilizer when they require it, in order to make the land, and hence the resettlement program, successful.

[1212] Alternatively spelled Do’oma.

The primary problem faced by farmers is lack of access to land. As Doma began as a resettlement region many of the people who were resettled have encourage family members from their original home to move to the area. Additionally, the government still moves people into the area, and often redistributes land from people already living there to the new residents. Many people also move into the area voluntarily as they believe that the area has better agricultural land, and greater access to markets. Most families hold about 1 hectare of land. There is a great deal of communal land in the area including grazing land, forest land, and a nearby national park. The latter two are protected by the government, although the forest is frequently segmented and given to new residents for farming. As more people move into the area, farmers believe that even more land will be taken from them, and from the forest. They feel that over time it will become impossible to farm enough food to feed their families because their plots will be too small.

Irrigation is very common in Doma and there is a tremendous difference between irrigated and non-irrigated land. For a farmer who holds 1 hectare of land, generally about one half of that is irrigated land. Most farmers do not own more than 1 hectare of irrigated land, even if they own more than 2 hectares of land altogether. Obviously, land which can be irrigated is more valuable than non-irrigated land. Large-scale irrigation projects have been undertaken by residents since being resettled in the area, including digging canals and ditches so that water can be properly distributed through fields. Non-irrigated fields are typically used to grow subsistence crops, while potential high value crops, including potatoes and onions, are grown in irrigated fields.

Farmers believe that their children will have better lives than they do working as farmers and would like them to continue working as farmers. Even though they want their children to work as farmers, 85 percent of children still graduate secondary school. Many parents have made investments in their land, and believe that such investments will provide in the future and ensure good lives for their children. With such investments, farmers believe that their children will be able to produce plenty of food for their families, even on a smaller amount of land. They feel that even though they sometimes struggle now, they were redistributed into a productive region, their families will succeed there, and the government is looking out for them.

A.10 Gara Godo

Gara Godo is situated in Sidmo province, with the nearest city being the densely populated Wolayitta. The village is about 1,700 meters above sea level and has poor soil. Gara Godo has suffered during all recent famines, including those in 1983, 1984, and 2003. Although the region appears to be fertile, and the entire region looks green, crops are generally not successful, giving the nickname “Home of the Green Famine”. The most common crops which are grown are barely and enset, although several types of maize are grown. Hybrid maize is preferred, when available, although typically seed is not delivered to the village in time, so it is generally not used. Fertilizer is also required for hybrids to be successful and it also suffers from a delivery timing problem. While hybrids are desired, due to their greater yields, most families grow conventional varieties of maize, enset, and barely for consumption.

The primary problems facing farmers are: 1) lack of land for farming, 2) soil degradation, and 3) lack of production of food crops. While many people have been leaving the area, families still have many children, increasing the amount of land required by each household in order to produce enough food. Most farmers hold under ½ of a hectare of land. The land was registered to increase security of tenure in the early 2000s, but there are still many disputes over land ownerships in the region. Some common land is still available, although it is used for grazing animals, and for meetings organized for the town. Most farmers do not believe that it could be transitioned into farm land, despite the need for increased agricultural land. Soil degradation is a large problem due to the scarcity of land and lack of fertilizer. Land is no longer kept fallow and no conservation practices have been undertaken to attempt to restore the land. Most farmers are concerned with producing enough food to feed their family in the current year, rather than planning for future years' crops.

Overall, the main problem in the region is the lack of food. Farmers are hesitant to diversify into high value crops, due to the risk of crop failure which comes with an unfamiliar crop. Although diversification is a traditional coping mechanism when land is scarce, and has been done by other villages in our survey. However, farmers in Gara Godo are unwilling to try new crops when they do not know the outcome. Some farmers have begun to grow coffee, as a cash crop, but have suffered as coffee plants take several years to produce. In the time between they have been forced to purchase food on credit, and other farmers believe them to be "suffering greatly"[13]. Due to the long gap between coffee planning and harvesting, as well as the perceived suffering, other farmers are hesitant to diversify to coffee.

Farmers do not believe that their children will be as well off as they are. All perceptions about the future were very pessimistic. Most farmers believe that education is the best option for their children, but believe that even education will not guarantee them

[13] This is simply a quote from survey participants. No people who were actually growing coffee as an adaptive strategy participated in our survey.

work in the future. This echoes other villages and farmers beliefs that college education o longer guarantees employment, due to the large number of people who now have college degrees. Most farmers would prefer their children to work off-farm making handicrafts or migrating away from the region altogether to Addis Ababa, or to different countries in Afica. Many parents have watched their children starve to death in recent famines, and do not want their children to see their own offspring suffer in the same way. Therefore, most would prefer their children to leave Gara Godo, and in some cases, Ethiopia, altogether.

A.11 Imdibir (Emdibir)

Imdibir is situated on 800 hectares of flat land, although it is located in a mountainous part of the Shoa region. Historically, the area has been considered unfavorable for crops due to this terrain, despite having good weather and abundant water sources. However, the village itself is favorably located and most households are able to farm on flat land. Due to the desirable traits of the region, it is quite densely populated. The primary crops grown include coffee and chat for sale and enset and maize for consumption. Wheat and teff are also grown, although only when hybrids are available. Hybrids are also preferred for maize, due to their rapid maturation and resistance to diseases. Although hybrids require fertilizer, farmers are generally willing to pay the cost, provided that fertilizer is available. In recent years timing has been problematic, so despite demand, it is not always possible for farmers to use it.

The primary problems faced by farmers are: 1) lack of access to land and 2) degradation of soil quality. Most farmers own just less than 1 hectare of land, but increasing family sizes have made it difficult to produce enough food for a family on that amount of land. Due to these constraints many households would like to leave the area, but cannot due to due to lack of money and lack of support in the urban areas. Many farming households cope with present difficulties with diversifying to other activities, in particular raising animals and selling handicrafts. Degradation of soil has become a greater problem due to the constraints of decreasing land size. Soil has been degrading slowly over time, but has increased recently due to lack of fallow practices, which stopped about ten years ago. Many farmers indicate a desire to revive fallow practices, as they did recently, but due to the lack of land, they are unable to do so. Instead, terracing has recently taken up, with the help of a Catholic aid organization. There has been some success in improving soil quality in those areas as a result.

High value crops have become more important over time. A large number of farmers are transitioning away from producing only coffee and chat as crops for sale, and beginning to include spices, avocados, and mangos. Fruits, in particular avocados and mangos have been in high demand in the capital, and therefore farmers have been able to get good prices. Other farmers, despite the success of others, are hesitant to give up other crops due to fear of prices decreasing.

In Imdibir farmers have mixed perceptions about how their children will fare in the future. Many believe that agricultural productivity will increase through improved technology, and if prices continue to improve, then their children will do well as farmers. Others are not as optimistic, and are concerned about growing population density and smaller farms. For those who do not think that their children will be successful as farmers, they believe that local non-farm employment and trading will be their best employment options. Education is important to parents, as well. Although education is less important than before, due to the difficulty in obtaining a job despite high qualifications, parents still believe that education can help children to be better farmers, as well as increase their odds of getting a job off the farm.

A.12 Somodo

Somodo is situated very close to the city of Jimma, in a major coffee producing region, located south of Addis Ababa. The area is densely populated, and is one of the only primarily Muslim villages in the region. The primary crops include coffee and chat for sale, as well as maize and enset for consumption. Hybrids are not preferred as local varieties consistently produce higher yields. Further, sale of hybrid seeds are tied to sale of fertilizer, which makes them cost prohibitive. Farmers who only want to purchase either seeds or fertilizer are unable to do so, and if they cannot afford both, most simply go without.

In addition to the problem of lack of access to inputs, the primary problems faced by farmers are: 1) lack of access to land, 2) poor soil quality, and 3) flooding. Most farmers own about 1 hectare of land, and most would like to have access to more, but all available land in the community is currently used for communal grazing land. The village ascribes great value to communal land and would prefer to keep it public. The farmers believe that the decrease in land availability is due to a large increase in family size, although most women believe that contraceptive use has kept this increase smaller than it would have been otherwise. The increased population density has caused degradation of soil quality. Land is no longer kept fallow for any period and attempts to improve soil quality through digging ditches and planting grass have not been successful. Flooding is a related problem, as it further degrades the soil through erosion. Farmers believe that climate change is responsible for the increased flooding observed in recent years.

Many farmers have begun to diversity crops to a variety of cash crops, away from just coffee, in order to increase their opportunities to make money through selling fruits and vegetables. While coffee is consistently lucrative, many farmers have found that they can make more through selling chat abroad. Many also find it easy to grow other tree crops, including mangos and avocados. Beekeeping has also become popular, as pollinators can help to increase yields, and Jimma has historically been known for good honey.

Schooling is a somewhat contentious topic in Somodo. While the village is near to Jimma it is still too far for children to walk and there is no public school in the area. Therefore, children who are educated are sent to a private Catholic school in the area, which problematic as most families are Muslim. Most parents felt uncomfortable about sending their children to a school with a foundational base so different from their own, but ultimately determined that getting a good education was more important. Most children, as a result, are able to attend school through grade 10 at the Catholic school.

Most farmers are not optimistic about the future for their children. None believe that their children will be better off than they are as farmers. Due to decreasing farm size, increasing family size, and degrading quality of land, parents feel that their children will be better off in different professions. One woman in particular voiced the concern that her children do not learn as much about farming as she did as a child because they spend all their time in school. She argued that they could perhaps be better off as farmers if they were able to attend school part time and spend the rest of the time on the farm. However, due to the structure of the school, they must attend full time. She said that it was not possible for her children to be better off as farmers. Most parents echoed her opinion and said that their children would be better off migrating to urban areas, or out of the country altogether. As most families are Muslim, there was great optimism for moving to Qatar or other Arab nations and making a new life there. While most farmers in Somodo are presently doing well, they have little hope for the future of their children.